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THE MECHANICS *of* RECOVERY

By
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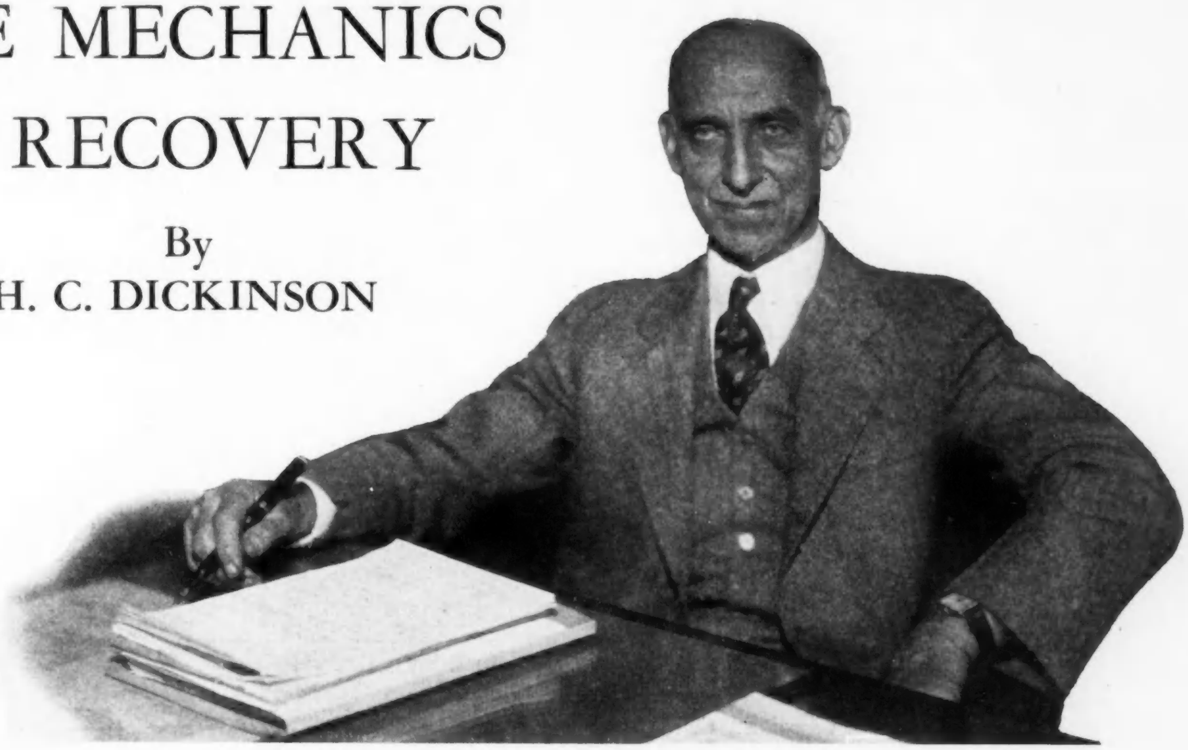

WE SHOULD get nowhere in science or engineering if problems were handled in the manner in which economic problems have always had to be handled. Progress in science has always been based upon the simple statement and use of basic laws. No such laws, with perhaps one exception, are generally recognized in economics.

The object of this address is to point out some apparently basic laws which may be applied to the present economic situation. We shall not presume to tell economists, bankers, or politicians how to run their business but shall try rather to show how certain results necessarily follow from certain causes, and to show how the relationships between these are clarified by the application of the basic laws here proposed.

I propose to show that the competitive economics system of a nation is in fact a mechanism, following, as does a machine, certain general laws; that severe inflations and depressions arise from a definite instability in the balance between capital goods and consumables, and that this instability can be controlled through adjustments of the mechanism itself without disturbing the present competitive system and with far less interference with personal freedom of action than we are accustomed to at present. This offers a means of securing, throughout the population, continuous prosperity, stabilized at any scale of living which the population desires to maintain by its hours of labor.

One must first lay a foundation of basic facts, five of which in particular will be formulated as basic postulates.

1—*The Law of Supply and Demand*

The first is the one generally accepted law of economics which appears universal like our laws of physics, the law of supply and demand. It means simply that, in any competitive system where money is used, price in general is controlled by the relation between supply and demand. While there are apparent exceptions to this law, it is obviously true in general and is in fact a universal law of nature where there is competition.

2—*The Economic Unit*

The solution of almost any engineering problem requires that we isolate some complete unit so that it can be examined by itself. For instance, if we require the heat balance for an engine, we must measure what goes into this engine and what comes out and consider what happens inside.

Applying a similar method to the study of economic balances in the United States as an example, we have certain facts to deal with.

Within the United States there are normally some 49,000,000 people working, producing goods and services which in turn are used by the entire 125,000,000 population. There may be a small net balance of exports or imports and some variation in the net stock on hand but these are comparatively small correction terms. It should be noted that exchange of goods and services in kind with other nations does not affect the balance between production and consumption.

The output of goods and services may be divided into two classes: those which are consumed and those saved for future use, generally to increase or improve the national plant. Using economic terms, these are consumables and capital goods. It should be noted that some 75 or 80 per cent of consumables consist of *services,* not goods.

In this system also we have a certain amount of money in the form of currency and credit. The prime object of the money is that of a "catalyst", to facilitate the free exchange or distribution of goods and services. Money, like a catalyst, is not consumed in the process but remains in circulation. It has other objects also, which will be referred to later.

This, in general, is an over-all picture of the *Economic Unit,* or mechanism, with which we have to deal, and all

[This paper was presented at the 1933 Annual Meeting of the Society. The author is President of the Society and is chief of the division of heat and power, Bureau of Standards, City of Washington.]

that is said later will *refer to such isolated economic units,* isolated in the sense that we can make corrections for any net exchange of *goods or services for money or credits.*

3—*Competitive Distribution of Income*

The next fact to be considered is the distribution of goods and services among the different members of the population. This is most readily expressed as distribution of *income* in money, meaning in this case, substantially, *net* income.

Examining the facts, we find that competition has always distributed net incomes according to some sort of a probability curve, brought about by the existing complex combination of competition and chance or accident. In any particular nation and at any particular stage of social progress the distribution appears to have a certain *normal* form about which it fluctuates due to all sorts of economic changes but toward which it always tends to return. In fact, the general form of this normal distribution probably has not changed greatly throughout history.

This concept of a "norm" of competitive distribution of income is by no means a familiar one but appears important. To explain this further, if we pick any man at random from a representative crowd, the probability that he will turn out to have an income of $1,000, $10,000 or $1,000,000 per year can be expressed in the same way that we could express the probability that any molecule in a mass of gas would have any one of various velocities.

Such a concept as this may at first be abhorrent to many, but we are dealing here, for the present at least, only with impersonal facts. The analogy between mankind and a gas is almost too close for comfort. Men of widely varying competitive ability correspond to molecules of different mass. The normal distribution of incomes takes place through a complex system involving competitive ability and accident, with the existing result, however we may like or dislike it.

Two important features of this "norm" of distribution are (*a*) its marked stability as shown by the tendency to reestablish itself when disturbed, and (*b*) the surprisingly disastrous results when any such reestablishment is in progress. We might discuss both these points at great length, but I believe that both will be fully appreciated on careful thought. For instance, the stability is emphasized by the popular saying, "Taxes are always paid by the consumer," which simply means that almost any form of tax levy shortly becomes fully distributed. The second point will be clear if one contemplates the general disastrous results of changes in taxes and tariffs, of bonuses, price fixing, and so on, all of which are *solely disturbances of the normal distribution of incomes.* If such devices were used correctly to restore an already disturbed system, the results would certainly be good, but good results in practice are rare. We would emphasize again (*a*) that taxes in particular are solely a redistribution of incomes—not a loss of incomes—just as in a game of poker there is no loss or gain for the group as a whole; (*b*) that taxes can be nonselective so that they do not disturb the normal income distribution; and (*c*) that nearly all the discomforts of taxation are due to its present selective character. (This has been repeatedly shown by others and will be enlarged upon later.)

In what follows we shall postulate that *there is a "norm" of income distribution for the existing social set-up, toward which incomes tend to return and that artificial disturbances of this "norm" should be avoided.*

4—*Conservation of Money*

In physics and engineering two of our oldest and most potent postulates are conservation of energy and conservation of matter. These are, to be sure, buried so deep that we seldom think of them but they are a basic and essential part of our thinking.

In economics, *conservation* of *money* is a close parallel and of perhaps equal potency as a foundation for clear thinking, but seems seldom to have been recognized outside of purely academic circles.

The latter postulate is, to be sure, not so simple as conservation of matter because money, including both currency and credits, is subject to expansion and contraction. The concept therefore must be applied with care.

Obviously, within any isolated economic unit currency is substantially constant for short periods of time, usually being capable of controlled expansion or contraction to meet changing needs. Credit, however, expands and contracts with only very limited control. Its changes are reasonably well defined and in general its changes in volume follow the demand. It is clear, therefore, that for any particular set of transactions money is neither made, nor lost, nor spent, nor saved insofar as the economic unit is concerned.

Money placed in circulation by an issue of currency or of credits (of certain kinds) remains in circulation. *Money collected as taxes expended within the unit is at worst only redistributed*—not "spent." It is still conserved in the hands of someone. If an expansion of currency or credit is made to handle any particular set of new transactions, the total amount of "money," to be sure, will be increased and vice versa, but the mere act of collecting and expending money within an economic unit is primarily a part of the existing system of distribution. In that sense conservation of money is a valid concept and is absolutely essential to a correct view of the economics of all money transactions. We emphasize this very obvious and oft-repeated principle because it appears to be almost universally ignored in so-called practical economics, especially when related to taxation.

5—*Returns on Captial Come Only from Earnings of Business*

This postulate, which has been developed very fully by such authors as John Maynard Keynes in his Treatise on Money, and by many others, is stated here like the other four without apology, since it, like them all, was arrived at independently as an inevitable consequence of the present analysis. To make this clear will require proper definitions of capital and business, which are given here only in very brief terms, and more fully in an appendix.

For present purposes, *Capital Goods* are defined as all those things, tangible and otherwise, on which interest or its equivalent is paid or expected. Some of its elements are: improved land, buildings, tools and equipment, patents, organization, established trade-marks.

Capital, when the term is used, will stand for one of the various monetary evaluations of capital goods; for instance, earning power and sales price.

The term *Social Capital* will be used to include all forms of public or quasi-public property which *does not draw interest,* as roads, schools, hospitals, parks, public buildings. These in general represent savings, compulsory or otherwise, devoted to general social welfare or progress.

The term *Interest* will be used for the return on capital

or capital goods, to include all forms of payment made directly for the use of capital; *not including, however, earnings* due to good management or good fortune in excess of current interest rates. (See Appendix.)

Business is here used to express the sum total of all transactions which have to do with the production and distribution of goods and services. This is the sum of all activities through which competitive distribution of income is accomplished. It should be noted that this definition draws a sharp line between *business* and *capital*. Such a distinction usually is not made, although it is in reasonable accord with accounting practice. In general, *capital* is what one might borrow and pay interest for; business is the process whereby the capital is used and a product turned out and distributed.

These brief definitions will indicate that the terms are used in a completely comprehensive sense, more fully defined in the Appendix.

Business in the aggregate yields a return which can be paid out as interest for the use of the capital goods which it employs. Capital goods are accumulated savings, and interest offers the means whereby people are induced to save for needed capital. It is perfectly obvious, therefore, that the total amount of *interest* which can be had for the use of capital goods is *limited absolutely by the earnings of business*. If new investments are made in capital goods after this limit has been reached, a sufficient amount of new business must be done to pay interest on the new investment or else the investment is completely wasted.

This analysis, of course, like all our others, applies only to an entire economic unit. One firm or business may increase its own capital and its own business to match, but if this is done at the expense of other firms without a net increase in the business of the entire economic unit, the total value, expressed in earning power, of the capital goods in the unit has not been increased by the transaction; the equivalent of the entire new investment is therefore a dead loss. If this particular concern making new investments earns its interest, this is due only to successful competition in which this unit has profited at the expense of others, and the economic unit as a whole has neither gained nor lost, except that the population has lost the labor which went into the useless capital (savings).

From the standpoint of the economic unit, therefore, new investment in capital goods is a total loss at such a time unless a corresponding net increase in total business accompanies the new investment and is sufficient to pay interest on it.

Character of Foregoing Postulates

Two of these five postulates are qualitative only; namely, the *law of supply and demand* and the *competitive distribution of incomes*. The latter, we believe, could be reduced to a rather definite quantitative basis if sufficient information were at hand.

Two of them are quantitative; namely, *conservation of money* and *the balance between business and interest on capital goods*.

One, the *isolated economic unit*, is descriptive. It simply sets a limitation or field within which the other four postulates are valid.

We have devoted some time to the explanation of these five postulates, first, since they are basic to the entire discussion, and, secondly, because their appreciation requires in some cases such radical revision of current beliefs and opinions that an *accurate* understanding of them is particularly important.

Causes of Inflations and Depressions

From the beginning of history we have had inflations and depressions. Some have been short and mild, others long and severe. A few even have ended in the downfall of civilizations and the decay of races. Perhaps the world's most spectacular one occurred before recorded history. Within a period of less than 200 years, Egyptian civilization reached an astounding peak of both knowledge and mechanical skill which culminated in the creation of the great pyramids, and then faded from sight never to revive.

Looking at a composite of all these occurrences, one is struck by their similarity. Moreover, one striking characteristic occurs to the engineer. *They all alike strongly suggest a system in unstable equilibrium.* In fact, one is convinced that there must bin the basic economic balance, or unbalance, some set of factors which are inherently unstable in the same sense that some mechanical systems are unstable. Economic cycles are not definitely periodic, like the swing of a pendulum, but there is no good reason to expect that they should have a definite periodicity.

So striking do these things appear that an attempt was made some time ago to deduce a logical explanation, with a result which is remarkably consistent with all of the facts at hand.

It is clear that depressions commonly follow inflations, hence it is probable that both are parts of a single disturbance. These disturbances have occurred at all levels of economic development and under all sorts of racial and social conditions. Any one basic cause therefore must necessarily be of a most primitive sort. To correspond with the obvious instability, such cause must involve factors of such nature that, when a disturbance is started in one or either direction, this disturbance tends to grow in magnitude, in other words, is cumulative.

Balance of Capital Goods and Business Needed

Considering now the most primitive economic factors, one immediately notes the need of a correct *balance between capital goods and business*. The primitive tribal weaver or arrowmaker requires tools or equipment and must turn out and dispose of a product. The one represents *capital*, the accumulation of savings (in labor); the other, current *business*. Moreover, there must be *a suitable ratio* between these two portions of his expenditures in labor. If all his time went to making tools he would soon starve. If all were spent in production without tools, no progress would be made, and if there were competition he would soon go out of business.

This same balance applies in exactly the same way to any modern business or industrial plant, large or small. If too much income is spent for equipment at the expense of output, failure is in sight. If capital goods are neglected, the result is also failure.

This same essential balance applies to the economic unit as a whole. Referring again to the fifth postulate, *capital goods cannot earn more than business can yield*. The welfare of the economic unit, therefore, depends just as definitely on *a proper relationship between capital and business as does that of the primitive weaver or the modern factory.*

Where an entire economic unit, or a nation, is concerned, however, the penalties are not so prompt and obvious, hence the condition usually is not recognized.

So far as the individual business is concerned, this balance or correct ratio between capital goods and output is not unstable, in the mechanical sense. If an excess goes into either capital goods or output, competition promptly corrects this error or else eliminates the business. *"Survival of the fittest" decrees that only those businesses can exist which maintain a reasonable approach to the correct ratio.* This fact renders the ratio stable.

Uncontrolled Ratio Leads to Speculation

A careful analysis of these same factors in the economics of an entire economic unit, as for instance the United States, leads to the conclusion that, in this case, unlike that of the single person or firm, the ratio between capital goods and business is distinctly an *unstable* one. It thus shows the second quality which seems to characterize a basic cause of inflations. Expenditures for total capital goods within the Nation are not controlled by any single board of directors nor are excesses promptly checked by competition. Moreover, capital goods are salable commodities which can change hands at a price. This price is subject to the law of supply and demand. If there is an under-supply or an over-demand, the price will rise; if an over-supply, the price will fall.

Consider in detail what happens in case of a small excess demand for investment in capital goods. Such demand may arise from any of several causes such as (*a*) an excess of savings, (*b*) abnormal economies, (*c*) too rapid liquidation of Government indebtedness, or any combination of these or various other causes which may throw on the market a small excess of funds for investment. The result in any case is an increase in *demand* for capital goods, or, in the ordinary sense, for capital—the securities and credits which represent capital goods. With the increased demand the price rises. The rise of price in this case is initially not the result of increased earnings but purely of increased demand. As soon as there is a rise in price, securities and credits, being a salable commodity, are sold at a profit, and, since capital is always held in disproportionate amounts by those in a position to reinvest, the profits of these rises are reinvested to a correspondingly disproportionate extent. This is true because too large a part of those who profit by this initial rise in the price of capital cannot or do not sufficiently increase business.

Effects of Price Inflation

Now it is obvious that this process of rise in price of capital goods is a highly *unstable* and *cumulative* one. This inflation is possible, of course, only through the expansion of credit, but this expansion is mainly the result rather than the cause of the rise in prices. Gambling in securities becomes general and is an essential factor in the increase of prices, but gambling *starts* as a result of the *initial excess demand for securities* which initiated the price increase. General commodity prices may change with those of capital but in general such changes appear to be superimposed on more fundamental changes in price level which arise from other causes.

Another most significant feature of this process is its direct effect on the norm of income distribution and on the amount of business activity. Not all of the profits from the sale of securities goes back into capital. Much of it is spent for consumables and thus goes to increased business, which greatly facilitates or *lubricates* the process of competitive distribution. Any such increase in ease of adjustment promptly increases business activity and total earnings, thus *justifying* an increase in capital goods and also encouraging further capital inflation.

All of these elements enter into the process of inflation and are of a highly cumulative nature. Inflations appear to progress in a general way along an exponential curve, or with increasing acceleration, which is in accord with the nature of the process as we have here analyzed it.

There are two particularly important facts about this process. One is that, due to its very highly cumulative character, the entire system gets entirely beyond control if the process is allowed for some time to go unrestrained. The best way to stop an oscillation is to stop it before it gets beyond a certain amplitude, or don't let it get going. The economic forces which develop from a possibly insignificant start acquire such power as to completely dominate the whole situation and get beyond control.

Peak Prosperity Could Be Permanent

The second important fact which we wish to emphasize and reiterate is that, *other than the unbalance between capital and business, there is no inherent reason* why the *business* prosperity occurring at the peak of an inflation should not be permanent.

Briefly stated, the situation is this: Within, for example, the United States, considered as an economic unit, 49,000,000 people are working in 1929 producing goods and services. About 75 per cent of the total product is in *services*. The 125,000,000 people in the Country are currently consuming these services and most of the goods. Some small amount of the latter are being exported in exchange for credits. There is still a demand for goods and services by the mass of population who do not have all they desire. There is sufficient currency to permit free interchange of goods and services. Credit is in abundance for all business activities. Distribution is not far from the competitive "norm," with a tendency, possibly, to more generous distribution in the lower brackets. *There can be no over-production in services because services cannot be stored.* There can be some over-production in goods, but in 1929 this actually was small except in a few special lines and there was ample demand among the population to absorb this surplus, with minor exceptions.

There was an unusual amount of flexibility in the establishment of the competitive distribution in 1929 between services and goods. During the period between 1920 and 1930, employes were being displaced from the production of *goods* and reemployed in the production of *services* to the extent of some 4 per cent each year. This was taking place, especially in the years of inflation, with very little unemployment and no hardships.

There is nothing in this entire picture that is inconsistent with an indefinite continuation of the same or even an increased rate of production and use of goods and services by the people of the United States. We could continue indefinitely to produce and consume this same amount of goods and services in all brackets of the income.

What went wrong?

Cause of the Collapse in 1929

Too great a percentage of income and of the unearned increment of capital was being put back into capital. The current business, great as it was, could not earn interest on all the new capital, or perhaps we should say on the *quoted values* of capital, new and old, being created by credit infla-

tion. As a result, people began, about 1929, to wake up to the fact that their profits were coming mainly from credit inflation. Securities they were buying at current prices were actually earning perhaps only 1 or 2 per cent on the cost. The inevitable result was a panic and the ensuing deflation and depression.

Inflation was not of itself the prime cause of the collapse but resulted in a great over-accumulation of capital, or of debt, on which current business could not pay a return, hence the collapse.

The inflation process in 1929 had gone entirely out of control, but if at any earlier period *business* could have been expanded so as to pay interest on the expanded capital, the destructive process would have stopped. This could have been done at any of the earlier stages of the process by *saving less* and *spending more*. The lower savings would have reduced the surplus capital and the greater spendings would have increased business and the possible interest return.

Savings, of course, can be only *loaned* or *hoarded*. If loaned, they constitute *debts* for someone, thus for the Nation; if hoarded, they make worse trouble. Thus the immediate cause of both the inflation and the ultimate collapse was the same thing; namely, over-accumulation of debts, that is, over-saving. It was the same old unbalance between what went into capital and what went into business, resulting in an unmanageable burden of *debt*. We must emphasize again that *in any economic unit savings and debts are exactly equal, except for the small total of hoarded goods or currency.*

Cumulative Effect of Retrenchment

This same factor, having resulted in the inflation, is the actuating cause of the depression—not only of the present one but of the typical depressions the world over, as we shall explain.

So soon as confidence faded and prices of securities fell sharply, immediate retrenchment became the order of the day. Men were thrown out of work for lack of purchases. Puchases fell off at a rapidly cumulative rate for lack of employment. The complex economic and social forces through which this came about and the reactions that followed defy analysis. But such an analysis is not necessary. We have the over-all facts. In the course of three years or so, employment fell off by about 10,000,000 people and total net income of the Nation by \$45,000,000,000. The dismissal of an employe to make a saving in wages resulted in a drop in net national income on the average of about \$4,500 for each \$1,200 saved in wages, a ratio of about 4 to 1. This factor would be somewhat modified if calculated in terms of commodity values on account of the current drop in both commodity and wage prices, but the startling disparity still remains. The depression is highly cumulative, since each discharge of an employe results in a dismissal of two or three more employes somewhere else.

For a particular firm or business, a reduction in payroll by the dismissal of an employe, *in times like these,* generally will not result directly in an equal decrease in the income of that firm. Otherwise such dismissals would not be made. In the Nation as a whole, however, the *loss of income* has been *some four times* the *saving in wages.* If the same calculation is based on total cost of wages instead of on number of men employed, the corresponding factor is about 2 to 1; that is, a reduction of \$1,000,000 in total payrolls results in a reduction of about \$2,000,000 in total net incomes. Thus it is only somewhat less disastrous for the Nation to reduce wages than to discharge employes, but either is highly cumulative. It appears that this cumulative factor must be due directly to the disturbance of the income-distribution norm by throwing people out of work or changing the wage distribution.

Whatever the cause of this disparity, it has immediate results of dire consequence. *On a total net income of \$86,000,000,000 in 1929, we could not pay an adequate return on the then existing capital debt. On a \$40,000,000,000 net national income in 1932, we are far less able to pay interest on the capital debt for this year.* So much for the effect of reduced business.

Loaned Savings the Basic Cause of Disturbance

On the other hand, the need of personal and corporate solvency and the psychology of a disturbed income distribution have led to maximum possible savings. But savings must be loaned (that is, invested) or held. If loaned, they become debts for someone. Necessarily, therefore, the following equation is an exact one for the Nation as a whole, except for foreign loans:

$$\text{Savings} = \text{Debts} + \text{Hoardings}$$

Hence, in the face of a necessity for reducing the national burden of capital debt, to bring it in line with present reduced ability to pay interest, we have an enormous *demand* for investment; that is, for increased *debt*. The excess demand for investment which started the inflation is still with us, preventing recovery by still maintaining or increasing the unmanageable burden of *capital debt.*

There has been much doubt as to the possibility of a single basic cause for major economic disturbances. What we have set forth here has all the earmarks of such a basic cause. Burdens of *debt* are age old and world-wide, hence a possible cause of disturbances through history. We see no other factor in the problem which is thus universal.

Over-accumulation of debt is essentially a cumulative performance and tends to increase rapidly when once started, thus possessing the quality of instability which appears to be a universal characteristic of major economic surges.

The process of over-accumulation comes about through a universal characteristic of the *competitive distribution of incomes* in that a disproportionate portion of income commonly accrues to those who must or will reinvest in more capital; that is, increase total *debt*. *The over-accumulation can occur and often has occurred by a more gradual process than that of violent inflations.* Thus a depression may be brought about without a preceding inflation.

Both inflations and depressions are cumulative as to debt increase, and when inflations have gone far they can develop economic forces which dominate all other factors. This analysis therefore points out a process which possesses all the characteristics of a single universal and basic cause of major depressions. We have been able to find no other possible cause which is of this general nature. *Therefore the over-accumulation of debt, beyond the ability of business to pay fixed charges, is considered the one underlying cause of major economic depressions.*

Excess of Debts Causes Nations To Fall

If the process goes too far so that it is not possible to realize a business profit beyond the interest requirement of fixed indebtedness, there is *no way out* except through repudiation of debts. Business cannot progress without a

surplus. A chronic condition of this kind appears repeatedly to have been the cause of the complete economic collapse of nations such as Rome and Spain, and of the long period of stagnation during the Dark Ages in Europe. Post-war depressions have often been particularly severe, and the major economic catastrophes seem to have followed wars. The reason is obvious. Wars, from times out of mind, have left a heavy burden of fixed indebtedness. This burden, superimposed on that acquired through an inflation or other causes, greatly increases the danger that a deflation will pass the deadline beyond which business cannot pay its fixed charges; that is, beyond which there is no recovery except through general debt repudiation.

As we have seen above, a deflation is highly cumulative in decreasing total net incomes and ability to pay interest, faster than costs can be reduced. *So long as discharging an employe* reduces net national income by three or four times his salary, we cannot recover by discharging men. At the same time, "saving" tends to increase the burden of debt. Debts are being reduced at the same time, to be sure, by bankruptcies, repudiations and the writing off of bad accounts, thus tending to counterbalance the increase in debts. However, every conscious effort made to date seems to encourage the destructive forces and discourage the curative process of debt reduction.

The economic forces which led to the downfall of ancient Rome and the decline of Spain can be traced clearly on the basis here outlined. The conditions were different in the two cases but the results alike in the accumulation of an unmanageable burden of fixed indebtedness.

Egyptian-Mosaic Code Suggests Remedy

Germany after 1870 offers another interesting example. Germany won a short and decisive war with France without any great material loss and with only a moderate increase in indebtedness. A heavy indemnity was imposed on France and was paid up with unexpected promptness. Germany, on receiving these payments, which meant a temporary excess of goods not produced within the nation, staged a violent inflation. This, like that in the United States in 1925 to 1929, led to forced investment and over-expansion of capital debts, resulting in a deflation and depression of great severity. France in the meantime paid the indemnity, its incomes were distributed on a normal competitive basis, and the country prospered throughout a long period while victorious Germany was at a low ebb.

What happened in Egypt 5000 years ago is not a matter of record but we have some remarks to make which are only interesting speculations. This episode occurred not long before old Hammurabi wrote the economic and social code which has been handed down to us in the writings of Moses. In this code are to be found two simple provisions which, taken together, in principle at least, would make such economic surges as we have discussed impossible. It is a rather striking fact that the Hebrew nation, as a nation, never suffered a severe economic depression.

It should be stated that these analogies with the Mosaic law did not occur to us until very recently—long after the basic principles were evolved.

One very important fact is that the only danger from an excess of debts comes from failure to expend the interest for consumables. There is no limit to the total amount of debt which could exist provided interest were not reinvested.

Remedies To Prevent Excess of Debts

While the beginning of an inflation or period of expansion and the danger point of a deflation both occur through the same sort of an improper ratio between capital or capital debts and business activity, they are different in character and may require different remedies.

The one object is to prevent an excess of debts. This might be accomplished by various means which statesmen and economists should devise. Two such means have been employed and we shall outline a third.

The first was the ancient provision for a limit to the *life* of all debts, as referred to above. A similar suggestion is attributed to Mr. Kettering in a recent interview. This is to the effect that bond issues might well be limited to a 20-year loan.

The second is understood to be on trial in Italy. It is reported to provide that new issues of securities must be authorized by the State and will be authorized only when national business warrants it.

Either of these means, properly applied, would be successful. In this analysis, however, all of our conclusions point to *reduced* rather than *increased* control by the governmental machinery and a minimum of disturbance of the normal competitive system of distribution. Moreover, it is as important and perhaps more urgent at the present time to find a means of recovery than to control a possible inflation.

In an inflation, as we have shown, the critical point is an unstable increase in *unearned increment* which creates an abnormal increase in capital debts. In a depression, the dangerous condition is a reduction in business combined with forced or voluntary retrenchment, again increasing the burden of debt relative to the ability to pay interest.

In both cases the sole remedy seems to require a diversion of money or product from *capital* to *business*. In a depression, the immediate object should be to bring the *total business* or the *net national income* up to a point where it can pay interest on existing capital. In the case of an inflation, the object should be to bring or hold the inflated value of capital *down* to meet the level of available income from existing *business*. Obviously, however, these two conditions represent only a difference in emphasis, since the final object in either case is to restore a normal balance between earnings of *business* or national income and the interest requirements of *capital*.

This suggests a unified system of controlling the entire situation which we shall outline in some detail, bearing in mind at the same time that it is not the function of an engineer but of a statesman or economist to work out the details of any such plan of action.

Proposed Three-Point Plan

Stated very briefly, the plan is, (*a*) in an incipient inflation, to divert a part of the unearned increment of capital to increasing *business;* (*b*) in a depression, to increase business and employment by increasing the number of people working, by a process which will cost nothing and yield a profit to all concerned; (*c*) in normal periods of prosperity, not to interfere with distribution.

To show how this can be done will require a review and emphasis of some points previously discussed.

(1) *The normal distribution of income should not be disturbed.* This norm results from a complex of forces not under

control, and experience has shown that any disturbance of it is likely to be disastrous.

(2) *Taxes* represent only a redistribution, not a loss, of incomes. This has been shown many times by economists but has not been greatly emphasized or generally understood. However, this feature of taxation is not a necessary one. Taxes can be made non-selective.

By a non-selective tax we mean one which does not in any way disturb the normal distribution of incomes. An ungraduated and universal tax on net incomes would closely approach this condition. Such a tax has certain very important characteristics which we shall emphasize because of their essential bearing on the proposed method of economic control.

In any *economic* unit, such as a nation or even a State or city, a non-selective tax collected and spent within the unit returns substantially dollar for dollar to the individual tax-payer. This is true because the money collected remains and circulates within the unit, and naturally distributes itself in accordance with the normal income distribution and, on the average, comes back into individual incomes in proportion to their size.

Such a tax then can be raised or lowered with no disturbing effect on individual incomes. Moreover, such a tax remains non-selective when price changes occur, as in a depression, whereas selective taxes, such as those on real estate, become destructively selective at such times. This is because, under steady price conditions, a tax on real estate or any other single class of property becomes evenly distributed in the course of a few years through automatic adjustments of rents, prices, interest rates and the like. If a marked change such as a serious drop in prices occurs, the *relative* tax burden on real estate is suddenly increased in the same proportion. The tax therefore temporarily becomes highly selective, overburdening the owners of real estate. In the present depression, this form of taxation has become intolerable in some cases solely because of the *selective* character of the tax. This has arisen from the drastic change in prices and in general income distribution.

Advantages of Non-Selective Taxation

The railroads present a sad picture of this kind. Railroad taxes built up in normal or prosperous times are high. So long as times remained normal, freight and passenger rates and general competitive conditions distributed these taxes with fair uniformity throughout the population and no great harm was done. In a depression, however, the railroads are left with reduced earnings and a highly selective tax burden which is destructive. Again, if all taxes were non-selective in the beginning, no such difficulty would arise through changes in price levels. We would emphasize again that any tax assessment, however *selective* it is to begin with, becomes distributed, automatically, generally throughout the population, through natural competitive processes but any marked change in price levels seriously disturbs this adjustment and makes trouble. If the assessment is non-selective to begin with, this difficulty does not occur.

Another most important feature of non-selective taxation is that it may be used at times to the great *profit* of all tax-payers. If there are people unemployed, we have seen that the *reemployment of them adds to the total net income of the Nation (State or city) from two to four times what they are* paid in wages.

Thus, if the Nation, State or city, in times of unemployment will adopt a *non-selective tax* and use part of the proceeds in giving useful employment to people who otherwise are unemployed, the total net incomes will be increased by some such an amount. In effect, therefore, each tax-payer will receive again in income at least as much as he has paid in taxes plus a probable net profit of from 100 to 200 per cent, the community will have the benefit of whatever work is done and the man employed will have his normal wages.

This statement will be difficult to accept because it is so contrary to fixed beliefs, but it is mathematically correct except for the size of the profit, which, however, is necessarily large.

Divert Part of Surplus to Consumables

(3) *Capital Inflation.* When an inflation starts, as previously noted, it normally begins with an increase in the price of investments above their current earning power. This represents an *unearned increment.* This can be reinvested in capital at a normal interest rate only if business is increased enough to earn the added interest charge. The real value of capital does not increase in the absence of an increase in business, and the excess investment, in the aggregate, is a *total loss.* Worse than that, if allowed to go on it will cause an inflation resulting in much greater loss later on.

This surplus, however, can be handled to the great advantage of its owners, as follows: If a sufficient portion of this surplus, as unearned increment, is diverted to consumables or social capital, the rest may be safely reinvested, since the first portion will increase business and the income from this increased business will yield the additional earnings necessary to permit payment of interest on the reinvested portion.

It is evident that no single individual, nor even one entire industry, can by itself apply these principles, since the benefits would accrue to the whole Nation at the expense of the individual in question. Only when the principle is nationally applied can benefits to *all* be assured and legislation by the National Government, or *concerted* action by the States or subdivisons thereof, offers the only means of making them effective.

These devices offer a simple means of controlling most of the ills of capitalism without sacrificing any of its virtues.

There follow some suggestions as to how it can be done.

Methods for Bringing About Recovery

Ten million people should be put to work, and it is worth about $4,500 in net national income to put each back at his old job and old wages, or perhaps $2,500 each to put them back at some other job. Several methods of doing this are possible:

(1) Commercial loans by banks have been predicated recently on the most drastic possible reductions in personnel and expenses on the part of industries requiring such loans. This course decreases the net income of the community, as already noted, through reduced employment and in the end endangers the stability of the banks themselves. This procedure is dictated, to be sure, by the need of protecting individual accounts. The banks, however, could well afford to liberalize this policy; economize the *maximum employment* of labor rather than the *minimum* and protect themselves against individual risks by means now available.

The net result would be a certain and large profit to banking as a whole, through both increased business and the advance in security values which would follow.

(2) Municipalities burdened with selective taxes could reduce these tax levies in proportion to the reduced value of

real estate or other taxables and supplement this with a non-selective tax levy. Such a tax can then be increased as much as necessary to maintain all current activities and reemploy as many of their unemployed as can be placed in useful public work.

The result of this course would be a return to the tax-payers of their entire tax payments plus from 100 to 200 per cent profit in increased incomes.

The foregoing two methods, to be successful, require concerted action throughout the Nation.

(3) The National Government might broaden its income-tax base and eliminate the selective feature of this tax so far as is legally possible, then adopt some such procedure as just suggested. A simpler and more effective solution, however, is proposed below.

A Simple and Effective Solution

Investments, or capital, sell at a low price during a depression because of reduced earnings. An increase in business or in total net national incomes will result in a large rise in value of capital because of the increased earnings which will result. This rise, it should be noted, is not an inflation unless the prices of securities rise above the capitalized value of their earning power. It is proposed, therefore, that the National Government adopt a special tax to be assessed against a *rise in values* of capital; stocks and real estate representing the more important sources of receipts.

To bring about a rise in price on which the tax could be collected and which is essential to recovery, the Government should borrow on *short-time loans* whatever is needed to start a recovery, possibly $2,000,000,000 or $3,000,000,000. This special indebtedness should be fully amortized during *not more than five years,* through levies which should not amount to more than 1 or 2 per cent per year on the *rise* in selling price of investments.

So many plans have been presented for increasing employment through Federal action that we shall not add to the number but simply emphasize that it is of utmost importance that men be put back at their *old jobs* so far as possible and that such measures as are taken shall be *non-selective* as regards the *normal* distribution of incomes.

There is one very vital point in relation to recovery by the Federal plan just presented, which also has a bearing on the other proposals. This has to do with the main issue of over-accumulation of debts. The danger in the present situation is that fixed indebtedness may pass the point where business can earn a profit above capital charges.

This means that funds used for recovery must not go into capital. If this occurs, recovery will be halted and conditions made worse. For this reason public works which are "self-liquidating" should not be included, as they automatically increase the burden of capital debt. It should be noted that the proposed short-term loan differs in this respect from long-term bonds.

The means for preventing capital inflation through a tax on the unearned increment is an effective means for preventing over-investment in capital. This coincides with the above proposal for recovery and suggests a *unified national plan for stabilization of prosperity.*

How Control Would Be Applied

Adopting the basic plan of a stabilization levy to be assessed on the *increase* in prices of capital, the control would be applied as follows:

In times of depression, unemployment and low capital prices, the Government would borrow on short-time loans, anticipating a rise in prices. The proceeds would be used to increase employment and raise the national income level. This would result in increased earnings of capital and an advance in prices, a few per cent of which would be required to cancel the short-time loans. Thus the owners of capital would profit by a rise in security prices and real values as well and would pay a small percentage to the Government for the service of raising the prices. This is a service which can be performed *only* by the National Government in the manner here suggested.

In times of incipient inflation, when capital prices tend to rise above the capitalized value of earnings, the Government would tax this difference, or *unearned increment,* and put the proceeds into circulation to raise the total net national income. The resulting increased earnings would permit profitable investments of the remainder of the increment, which otherwise would be a total loss.

The levy on the unearned increment, since it is to play the part of the "restoring force" of a system in stable equilibrium, must have the characteristics of such a restoring force; that is, it must increase as the displacement from the equilibrium position increases. Needless to say that such levies should be *non-selective*—levied proportionately against all forms of capital so far as practicable. Whether such a levy against real estate could be made practicable seems to be a question.

In normal times with no serious unemployment and no incipient capital inflation, no Government control should be exercised. In fact, the system would act like an engine governor set to maintain a normal range of speed. Only when the speed went outside this range would the governor respond.

Some adequate agency, such as the Federal Reserve Board for instance, would be needed to actuate the governor when needed. This would require a means of determining, by collection of data, when prices of capital exceeded the capitalized value of earnings, in order to check an inflation at the start.

What a Depression Remedy Must Do

While we have suggested what we believe are wholly practical means of accomplishing economic stabilization, we refrain from enlarging upon them in order not to distract attention from the basic principle involved. Moreover, we make no pretense of being bankers or economists and there are doubtless means other than those here suggested for accomplishing the same object. The present plan was developed merely to demonstrate that the thing can be done practically and without important disturbances of any of our present laws or customs. Any device which maintains the necessary ratio between business and capital indebtedness without such disturbance will accomplish the result; that is, any good governor. In order to be effective, however, any remedy for depressions, we believe, must be consistent with the following precepts:

(1) It must put men to work, so far as possible at their old jobs.
(2) It must prevent further discharges of men or reductions in current purchases of consumables.
(3) It must abate the present disastrous selective effects of taxation; with this accomplished, total taxes are shown to be unimportant.
(4) It must prevent such immediate expansion of capital debts as might nullify the benefits of increased business.

As for these four cardinal points, present trends appear to be as follows:

(1) No effective moves seem to be in progress to put men back at the old jobs, except such as are being made by industrial leaders, hampered by the "conservative" attitude of the banks as regards commercial loans.

(2) There is a most consistent and far-reaching propaganda for further reduction in personnel, particularly those employed by the public, as a means of reducing taxes. This will reduce total net income by more than four times the amounts saved.

(3) Tax proposals are very largely aimed at further extension of *selective* taxes. However, a non-selective tax, such for instance as a universal income tax, if entirely non-selective would yield a net profit *to each taxpayer* of from 100 to 300 per cent of the total tax collected, provided the tax were spent in employing men *at their same old jobs*.

(4) There is a strong tendency, due to the urgent pressure for further new investment, to expand the capital structure through increased debt, particularly in public debts. These bear low rates of interest it is true, but, even so, each increase in debt must be accompanied by an increase in business which will pay the new interest charges.

We conclude as follows:

The present depression can be dispelled, and that promptly. Prosperity can be restored and made permanent.

These results can be accomplished without at all disturbing the "capitalistic" systems.

The present trends of financial, business and political leadership are opposing recovery.

The natural forces of society are mainly acting toward recovery.

Recovery probably will take place in any case, slowly of its own accord, but rapidly if correct policies are followed.

These we believe are engineers' conclusions, based on economic facts and the familiar processes of reasoning followed by engineers and physicists. They are here presented to engineers because we believe they offer a glimpse of what can be done for all of us when the abilities of engineers are really mobilized on the broad project of making a better world to live in.

APPENDIX—DEFINITIONS

Capital Goods

The term "capital goods" is used in its usual sense in distinction to *capital* as expressed in terms of money. As here used, it includes, however, not only tangible goods but the intangible values such as organization, good-will, patents, training and experience; in fact, all the items which might properly be included in a statement of capital by a firm or individual. The term "capital goods," however, is used only to express the *actual items,* not their estimated value in money. Thus a certain contract or a certain organized sales force or an existing series of advertisements for an article is an element in what we have termed capital goods, without relation to any assumed monetary value which may be assigned to it. "Capital goods" as thus defined consist of all accumulated savings which are devoted to the promotion of future productivity or everything on which interest (which see) is paid.

This definition does not include one very important element in the economic set-up; namely, what may be termed social capital, defined later.

Capital

"Capital" is used to express the value of capital goods in terms of money. It includes also public obligations on which interest is paid, even though these are based on buying power rather than on specific capital goods. Capital may change rapidly with changes in economic conditions, and in fact may have any one of several values depending upon the basis of estimation, such as "book values," "present worth," and the like. "Capital goods", however, change in amount only by the addition, depletion or obsolescene of some of the elements.

Social Capital

The term "social capital," as used here and elsewhere, includes in general all those items which make up public or philanthropic property, including organization and so on. This distinction coincides very generally with the distinction made in tax assessments; social capital constituting, for the most part, those things which are exempted from taxation because not held or used for a profit. The real distinction from an economic standpoint, however, is that these things do not call for payment of interest. When such things as highways or bridges are built by bond issues, they become, to the extent of the outstanding bonds, capital goods as defined above. In other words, social capital includes all those things usually held for the general welfare, on which interest is not paid.

It is not necessary for the present purpose to distinguish between social capital goods and their monetary value. Not requiring interest payments, the monetary value of social capital is not significant in the general economic situation, once it has been acquired.

Money

When the term "money" is used, it includes both currency and credits; in fact, all negotiable securities which enter into business circulation.

Interest

In this discussion it becomes necessary to distinguish between the returns for the use of capital goods and the earnings or profits of business activity. In individual cases, to be sure, the two sorts of return cannot be exactly differentiated, particularly where capital ownership and management coincide. In a broad sense, however, the return on capital properly may be considered as equal to the current rate of interest; that is, the rate at which capital can be hired on "perfect" security. Whatever returns beyond this are received for the use of capital are properly considered as the result of management or good fortune, and as not a legitimate return on capital as such. If the rate of interest on bonds or the dividends on stock representing capital goods is above the normal interest rate, this excess represents in general an assumed risk in one form or another. If a rate lower than normal is accepted, it again represents a risk or gamble on a rising price.

For these reasons, the term "interest" is used here to designate the return which is had for the use of capital or capital goods.

Business

The term "business" is used here to designate all the undertakings of the population which are entered into for

(Concluded on p. 64)

The WHY *and* HOW *of* THE RUBBER-TIRED RAILROAD-COACH

By E. J. W. RAGSDALE

Railroads are facing a crisis in operating costs, the urge toward reduction of unnecessary weight has become widespread and the crusade for noise abatement is no longer to be denied, according to the author. The pneumatic-tired railroad-coach not only answers these requirements, he says, but anticipates a demand for a new traveling comfort.

The desire to rubberize railroad equipment is old but much fruitless research has resulted from directing it chiefly toward solid-rubber or cushion tires. Road and rail surfaces present entirely different problems so far as the tire is concerned. No uniformity of conditions obtains on highways but rails are even and smooth. A badly aligned joint such as would wreck a metal wheel makes no impression on a pneumatic tire. As simple as the tire problem may seem, its solution represents years of courageous and skillful research on the part of the Michelin company in France. Out of this has been evolved a rail-car tire which has a life comparable with that of tires in highway service and therefore is commercially acceptable.

Facts from tire-performance data are stated and it is shown that light coach weight is the major need. The Budd-Michelin rail-coach is described and also the Reading-65 rail-coach. Weight comparisons are made and rail-coach body-design is discussed, as well as cost of weight.

THE PNEUMATIC-TIRED railroad-coach is the product of two separate developments; namely, a wheel and tire adapted to rail service by Michelin et Cie in France, and a system of light-weight steel construction developed by the Budd company in America. Thus these two firms, so long associated through a mutual interest in the Budd-Michelin disc wheel for automobiles, extend their relations into a new field of transportation.

The time seems most propitious. Railroads are facing a crisis in operating costs, the urge toward reduction of unnecessary weight has become wide-spread and the crusade for noise abatement is no longer to be denied. The pneumatic-tired railroad-coach not only answers these requirements but anticipates a demand for a new traveling comfort. It is not merely a bus constrained to run on rails, nor is it a railroad car stripped to accommodate rubber tires. It is a vehicle conceived in the light of a better service and designed without thought of precedent or convention. Seldom has the engineer enjoyed wider latitude.

The desire to rubberize railroad equipment is old and much money has been expended in fruitless experimentation. One might also add needless, for effort has been directed chiefly toward solid-rubber or cushion tires. Such are foredoomed to failure, for the bearing capacity of rubber is slight compared with that of metal. The rail head is narrow and the load-carrying area can be established only by lengthening the contact. Solid rubber lacks sufficient flexibility; even pneumatics have to be specially designed toward this end. Lateral distortion does not increase the tread as in highway service;

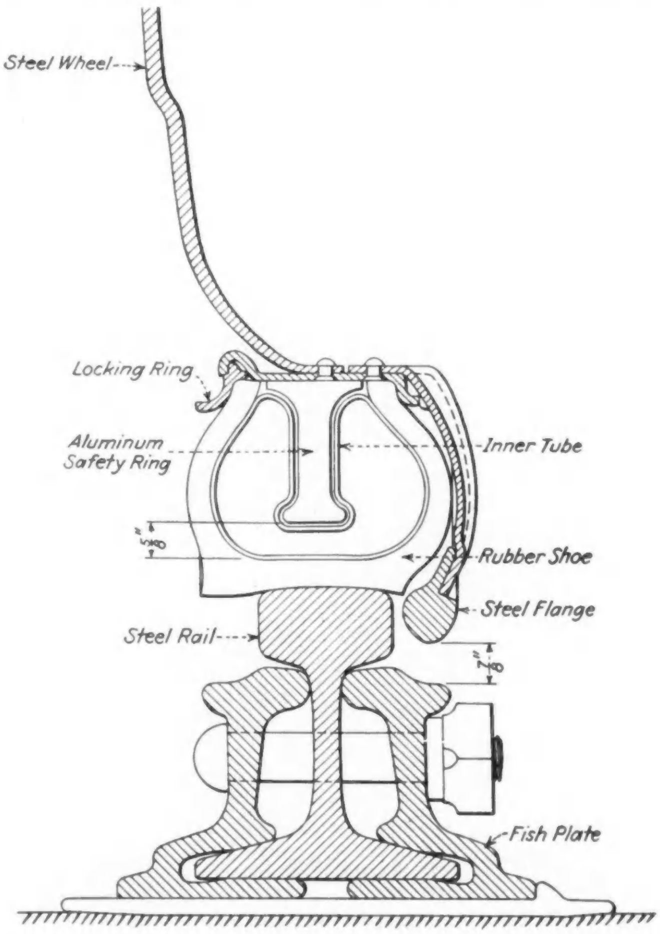

FIG. 1—CROSS-SECTION OF WHEEL, TIRE AND FLANGE, SHOWING DEFLATION RING

[This paper was presented at the 1933 Annual Meeting of the Society. The author is a Member of the Society and chief engineer, high-tensile division, Edward G. Budd Mfg. Co., Philadelphia.]

in fact, being unsupported, the sides of the tread may cause earlier breakdown of the tire carcass.

Road and rail surfaces present entirely different problems so far as the tire is concerned. The highway abrades tires, wearing down the tread, and is rarely smooth; bumps of widely varying height and character must be anticipated. No uniformity of condition obtains, but the tire is saved by its capacity to distort in any direction. Conversely, the rail is even and smooth. A badly aligned joint such as would wreck a metal wheel makes no impression on a pneumatic tire. Every condition is favorable except the narrowness of the rail head, and this will continue as long as roadbeds must serve the dual requirement of steel and rubber.

Solution of Pneumatic Rail-Tire Problem

As simple as the tire problem may seem in analysis, the solution represents years of courageous and skillful research on the part of the Michelin company in France. Out of this has been evolved a rail-car tire which has a life comparable with that of tires in highway service and therefore is commercially acceptable; but the work continues, for it is felt that the full possibilities of load or mileage have not been exhausted. The Goodyear company, operating under license from Michelin et Cie, already has made a notable contribution. That the present limiting load of 2400 lb. and the present certain mileage of 20,000 will be extended is fully expected. Certain it is that the rail surface will neither abrade nor snag the tire or subject it to unusual distortion. Further, railroad service permits operation at nearly constant speed; stops are anticipated and need not be abrupt.

The present tire, shown in Fig. 1, resembles a normal high-pressure tire but has a slightly flatter tread. It is 35 x 5½ in. and carries air pressure up to 100 lb. per sq. in. The area of contact under load is from 17 to 21 sq. in., and side distortion is scarcely noticeable.

The inner tube is made horse-shoe shaped in section to envelop the periphery and both sides of the deflation ring. This ring is attached to the wheel rim and extends well up into the shoe, so that, in event of puncture, deflection will be limited. Each tire carries a pressure gage attached to the wheel. In France, this is connected to an alarm system which notifies the engineer of any pressure below normal.

The wheels are of the conventional Budd-Michelin disc type, but the rim is extended along the inward wall of the shoe and terminates in a standard car-wheel-flange section. A clearance of ¼ in. obtains between each flange and the rail. The flanges suffer little wear, for rubber hugs the rail head and pneumatic-tired wheels do not "hunt" as do steel wheels. In fact, wheel shimmy is not confined to pneumatic tires; some of the worst cases known have been with steel-wheeled railroad trucks, and this effect cannot be cured by over-inflation.

Facts from Tire-Performance Data

The pneumatic tire for rail service has passed the experimental stage. Performance data have been accumulated from tests and scheduled runs aggregating 360,000 car-miles. They answer the questions invariably put by operating personnel as follows:

What happens in case of a puncture?

Nothing much. The shoe rests on the deflation ring and holds the wheel flange above fish-plates and other obstructions. A tire-and-wheel change can be made at the first convenient place.

Suppose you have a blow-out at top speed?

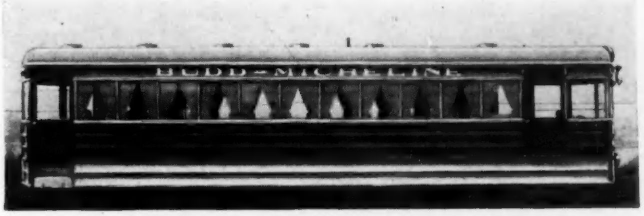

Fig. 2—The Budd Company's First Rail-Car
This Seats 40 Persons in Addition to Providing Suitable Space in Front for Baggage. Power is Supplied by an 85-Hp. Junkers Diesel Engine with Electric Transmission. This Car Has Been in Continuous Use for One Year, Five Months of Which Were in Scheduled Railroad Service

We did have. We had to shoot the tire. There were no untoward results.

Will not the tires bounce so as to interfere with flange guidance?

They do not. There are no bumps to provoke a bounce. The deflation ring stops any deflection of more than ½ in. Obviously, the rebound cannot be greater.

How about slipping?

Steel wheels have a coefficient of adhesion varying from 25 per cent on a dry rail to 9 per cent on a wet one. Pneumatics vary from 60 per cent on dry rails to 10 per cent in the case of a dew-coated rail. There is small variation between a dry or really wet track. Provision is made for the use of sanders. Most important, however, is correct design of the tire tread.

Since the tires insulate the car, how are signals operated?

That has presented a difficult problem. The voltage drop across the track is so low that excellent contact must be established. Even steel-wheeled rail-cars do not always operate signals. We have worked this problem out in cooperation with the engineers of the Union Switch & Signal Co. and have arrived at a satisfactory solution. Without entering into the intricacies of the electric pick-up and booster circuits, suffice it to say that contact with the rail is established through wire-brush blocks which are mounted between the wheels on both sides of the car.

So much for the tire. It has made the venture possible; however, to make its application practical, a suitable car structure is required.

Light Coach Weight the Major Need

In France, the rail vehicles show a strong bus tendency of design. The passenger load is relatively small, the appointments required are meager but the speeds are very high. In this Country we have felt that a rail-bus answers neither the demand of the traveling public nor the ideas of railroad management. While a cheaper mode of transportation is indicated, that cheapness dare not be obvious. The high cost of rail transport has not been chargeable so much to luxurious equipment as to a type of equipment that is too costly to operate. Correct the latter and the luxury may stay; curtail on accommodation and comfort, and the passenger volume that still remains will drift to other modes of transport.

Railroad revenue comes from passenger and freight traffic, and the percentage of each can readily be determined. Not so easy is the task of establishing the relationship of operating expense to charges for service. Few businesses have such an indefinite policy as the railroads. The industry has long been established. Both good and bad practices have grown up with it, and legislation often seems solicitous in

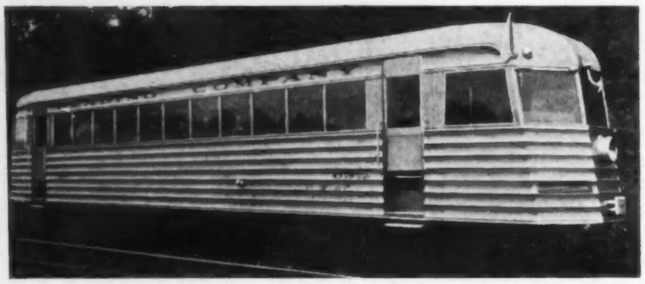

FIG. 3—THE READING 65 IS DESIGNED FOR ONE-MAN OPERATION, ACCOMMODATES 47 SEATED PASSENGERS AND IS PROVIDED WITH COMPLETE DOUBLE-END CONTROL

especially perpetuating the bad practices. Rate schedules are arbitrary and often illogical. In passenger service the basis of charge is the passenger-mile; in freight, the ton-mile. The first is a definite rate, but the freight schedule is subject to such variation that a 500-page book is required to list the classifications and charges.

In no book, however, will any mention be found of "proportionate payload." This expression has been given us by aviation and, incidentally, with it a new viewpoint for economic analysis. It shows the importance of the relationship between the weight of the carrier and that of the goods carried. After all, the least common denominator in any transportation service is the total weight moved, whether it be paid for by the customer or the hauler. The latter's business will profit in proportion to the amount by which the hauler can reduce his share. In freight traffic, which still pays, 1 ton of gondola carries 3 tons of coal; in the passenger end, which has been a dead loss for years, 2 tons of train carry 1 passenger.

Just how this weight is allocated is interesting. Take for instance a train operating between Philadelphia and New York City. Assume that it consists of two parlor cars and four coaches and has no diner or baggage car. Make a further assumption that every seat is occupied, and then we have:

	Weight, Lb.
Locomotive and Tender	476,000
Coal and Water	110,000
Two Parlor Cars	320,000
Four Coaches	420,000
380 Passengers	52,000
Total Weight	1,378,000

The hauler has contributed 3500 lb. of rolling equipment for the benefit of each passenger. If 3500 lb. of pig iron were offered as freight, the tariff would be $10.50, but the passenger responsible for moving this amount of equipment has paid only $3.24. The situation becomes further ridiculous when we find that the passenger might add his Pullman fare and still pay no more than if he had had himself crated and shipped as live stock.

This method of figuring is also open to criticism, but the fact remains that our railroads are hauling a great weight of non-revenue bearing iron, to say nothing of trying to operate under a schedule of tariffs which recognizes little relationship between the cost of service rendered and the charge therefor. The crated animal shipped in a box car weighing 43,000 lb. and costing say $6,000 brings the same revenue as a passenger in the Pullman which weighs 160,000 lb. and represents a cost of $85,000. This simply means that the roads charge what they can get and hope to balance their budget by compensating losses and gains.

Railroad officials are not now insensitive to this condition, nor are they impotent. The industry is long established and its very stability makes difficult any such radical changes as are indicated. That the losses incident to passenger traffic must be stopped or converted into a profit is evident, and it is also evident that wholesale junking of equipment would destroy financial confidence. Whatever is done must be by gradual transition. Any new type of vehicle must fit into the existing scheme, amplifying it and later, perhaps, replacing it. Its low cost of operation is a prerequisite; its comfort and luxury of appointment should anticipate future demand rather than merely meet the present demand. Railroads must bear in mind that the traveling public expects from them an accommodation far superior to what it accepts uncomplainingly from bus or airplane. Herein lay the failure of the self-propelled rail-car. Operation was somewhat cheaper than that of the steam train, but some rail-cars had accommodations almost as poor as those of a caboose—and lacked the sociability. In any case they have helped to lose rather than gain passenger volume.

Concept of Budd-Michelin Rail-Coach

It was in sympathetic appreciation of all this that the Budd-Micheline Rail Coach shown in Fig. 2 was conceived, and its reception bespeaks not so much the success of the design as the open-minded attitude of railroad organizations toward improvement, be its origin what it may. Railroad engineers have voluntarily followed each phase of the development, contributed ideas and refrained from imposing conditions that might defeat or deflect the aim. Herein lies the marvel, for precisely the opposite was gloomily predicted at the outset of the venture.

So far, four coaches have been put into service in the United States and 28 in France. Others are under construction. They vary somewhat to accommodate the conditions of their intended use, but all have in common the dual concept of more comfortable transportation at lower cost of operation. The principle is applicable to self-contained units operating under their own power, individually or in trains, or to trailers to be attached to conventional locomotives.

Lightness is the watchword in every case. Pneumatic tires require it; economy of operation makes it an absolute necessity. The empty weight varies from 480 lb. per passenger for a Diesel-electric-driven unit to 350 lb. for a trailer. But in no case can this be attained at the cost of safety. Railroads do not compromise in this respect. The

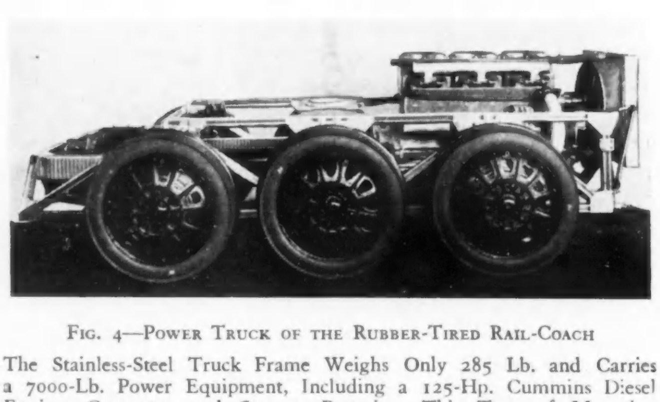

FIG. 4—POWER TRUCK OF THE RUBBER-TIRED RAIL-COACH

The Stainless-Steel Truck Frame Weighs Only 285 Lb. and Carries a 7000-Lb. Power Equipment, Including a 125-Hp. Cummins Diesel Engine, Generator and Storage Batteries. This Type of Mounting Promotes Quietness and Smoothness of Operation

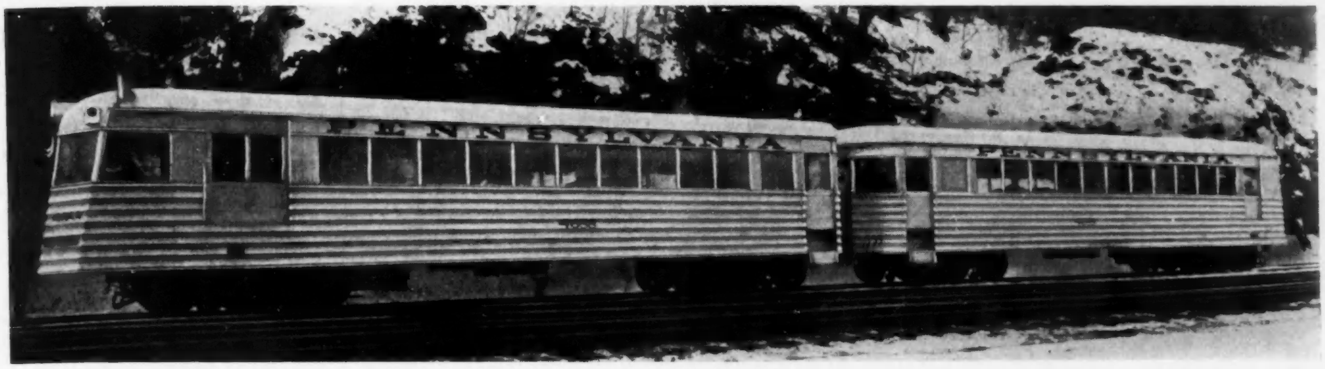

FIG. 5—THE PENNSYLVANIA TWO-UNIT TRAIN HAS A POWERPLANT IN EACH END SO THAT EACH UNIT CAN BE OPERATED SEPARATELY WHEN DESIRED

Double-End Control Is Provided To Facilitate Maneuvering In and Out of Stations

saving grace lies in the fact that collision effect is a direct function of mass. Extra weight aggravates the force to the same extent that it tends to resist it. By the same token the pneumatic-tired rail-coach, while subjected only to proportionate shock, is constructed to withstand many times this shock. A new development in stainless-steel structures has offered the answer.

This paper has dealt so far largely with a recital of conditions rather than with description of the rail-coach itself. This seems proper, since interpretation of an idea into metal and materials is an easy matter once the idea becomes clear. The responsible work has been that of crystallizing a program out of a mass of evidence that often is contradictory and vague. No such clear picture as has been presented in the preceding pages was available a year ago. Again in the interest of clarity, only one of the several types will be described. It is known as the Reading-65, shown in Fig. 3, and is chosen for illustration because it was designed for general utility rather than for some specific service.

Construction of Reading-65 Rail-Coach

The general specifications provide for a rail-coach to seat 47 passengers and to operate through city streets as well as over the main right-of-way. It contemplates a possible one-man control and a certain demand to run in either direction with equal facility. These conditions fix the detailed specifications. Double-end operation and one-man control eliminate mechanical drive; Diesel-electric power is indicated. Street operation establishes a turning radius of 55 ft. and restricts over-all length. This means the mounting of the powerplant beneath the floor. Engine, generator and battery are incorporated in one truck; the driving motor in the other. Railroad operation, with possible high-platform loading, fixes floor height and necessitates traps over the step-well. Doors, traps and folding steps, in view of one-man control, must be air operated from each end. The seats are reversible. With this outline, the picture begins to clarify, and a tentative weight analysis can be made. It sums up:

	Weight, Lb.
Body, complete	8,200
Engine, Generator and Motor	5,500
Trucks	5,000
Accessories and Signal Equipment	2,000
Car Weight, empty	20,700
Passenger Load	6,580
Total Weight	27,280

Allowing 2400 lb. for each of 12 tires, the total permissible weight becomes 28,800 lb. Then, with the weight and a tentative layout of the car established, the speed and acceleration are determined. These figure at 48 m.p.h. when the gearing provides for an acceleration of 1¼ miles per hr. per sec. This is acceptable, since the service conceived involves frequent stops. A high top speed is not desired, but good starting and stopping qualities are needed for general service.

A 125-hp. Cummins engine is suitable for the requirement. It delivers 72 hp. to the axles after deducting electric losses and all power consumed by auxiliaries. This gives a comfortable margin for reserve.

Engineering now groups itself into three divisions: power, running-gear and body. The first, by reason of personnel, is further divided into engine and electric sections. All these are interrelated through the weight-budget which, in designing to strict limitations, is as important and as difficult a function as is found in the administering of any budget system. The unforeseen items, and those purchased outside, are always chief offenders in weight violation. Such must be anticipated until suppliers can be brought to recognize the fact that weight may be as significant as price.

With weights of engine, generator, motor and batteries fixed at high figures, drastic reductions are indicated for all other departments. Most phenomenal, perhaps, is the design of the truck frames. One of these, shown in Fig. 4, has to carry 7000 lb. of power equipment, including engine, generator and storage batteries, to say nothing of supporting also one-half the body weight and passenger load. Actual weight of the frame is only 285 lb. Careful analysis and distribution of forces resulted not only in a frame many times lighter than those of conventional design but having factors of safety far exceeding any possible requirement. There can be no excess metal; every ounce is made to count. Wherever a stress line occurs, an appropriate stainless-steel member is built in. The structure finally looks like a problem in graphical statics.

Fig. 5 shows a Pennsylvania train unit. It has a powerplant at each end so that each coach can be run separately.

Body-Design Given Intensive Study

The body always demands the most intensive study. Not only are the forces complex in themselves, but doors or other accommodations will insist upon being placed where a main structure should occur. In this department, weights would run riot if not checked. This is particularly true of appointments and fittings The main structure represents only 9

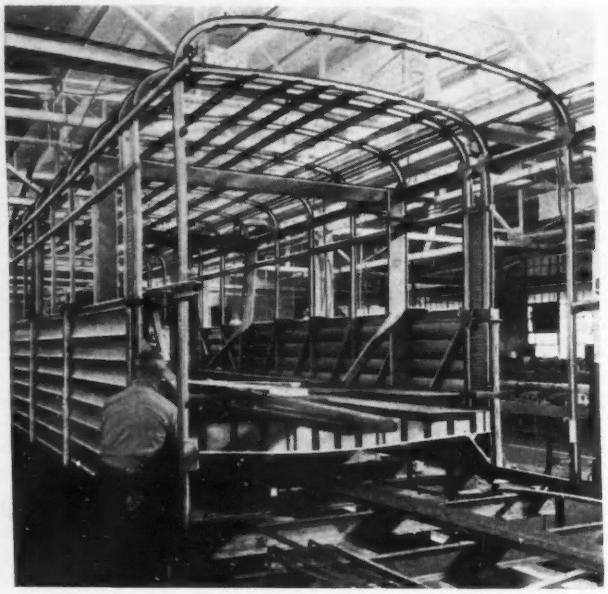

FIG. 6—THE FRAMING OF THE READING 65 IS MADE UP OF SUB-ASSEMBLIES, THE TWO ENDS BEING MADE IN SEPARATE JIGS

per cent of the total body weight; seats, even after drastic treatment, account for 15 per cent. Glass and cork-floor tiling run into large figures. One partition and door weigh more than the sum total of all floor beams. Air engines for operating the doors and traps are twice as heavy as the doors they operate. The horn weighs 25 lb., and there are two of them. And so on down the bill of materials. This preliminary weight estimate is no easy task, yet, until it is accomplished, there can be no thought of actual design.

A so-called accommodation plan is made for the start of the work. Weights are filled in as they become available; and, when complete, the truck reactions are determined. These are equalized by the shifting of truck centers. Then a first stress analysis is made. This shows shear and bending-moment curves. From these, an approximate fore-and-aft structure is laid out. The stresses usually do not run high when compared with the ultimate strength of the members, but further analysis probably will show excessive deflection. This study is elaborate, because it involves cumulative distortion of each successive panel, and errors will insidiously creep in. Careful checking is required.

In the case of the Reading-65 the first deflection curve showed ⅞ in., which was too much. The chord and shear members were strengthened at points of relatively high stress until the result was halved. The car was then built with an initial chamber which paralleled the deflection curve.

Side Paneling Takes No Stress

The Budd construction departs from customary practice in that the side paneling plays no part in the main structure (See Fig. 6). This at first seems inconsistent with economy of weight, but actually does not prove so and does have the advantage of preserving a sightly exterior rather than one showing the high lights incident to shear stressing such as are seen in cars with flat panels.

In the Reading-65 the main structure consists of two side trusses, the upper and lower chords of which are the window and skirt rails respectively. Into these is built a Pratt or N-truss, with the side posts serving as verticals and with diagonals secured between them. The outer paneling is fluted, which not only adds to the appearance, but prevents its being stressed. In this car, it was not thought practical to use the roof as a main strength-member, although it is the equivalent in stiffness of a 15-in. I-beam. No opportunity was afforded to tie it into the structure as a whole. Deadlights or diagonals would have been unsightly or inadmissible. The roof was, however, considered to serve in reduction of normal deflection and to carry the overhang at each end.

Use of Roof as Strength Member

In other cars under construction, the roof becomes a main strength-member and is most effectively utilized. There, however, it is possible to tie it into the lower portion of the car by suitable shear members. The window belt falls in the neutral axis and becomes of secondary interest. Temptation to utilize roof and floor as integral parts of the main structure is naturally strong. Both represent a substantial proportion of the total body weight and, though designed to serve other purposes, these are not defeated by structural use. Steel roofing and floor, if correctly designed, can be not only lighter than those of soft materials but can add materially to strength and safety. Further advantage accrues by tying the floor into the draft gear.

The means for translating these theories of construction into metal and the rôle which stainless steel, together with Shotwelding, has played toward full realization of the general scheme has been the subject of other publications. Duplication would unduly lengthen this paper. Suffice it to say that stainless steel not only offers unusual physical properties but, through its resistance to corrosion, permits the use of very thin gages. Its economical application results in quite unconventional shapes and sections. A mere substitution for ordinary steel accomplishes nothing but needless expense. The base cost of stainless steel remains high, and this brings up the point of just how much one can afford to pay for weight reduction.

Economy of Weight Saving

In aviation, the problem is comparatively simple because operation is in defiance of the law of gravity and every pound saved represents a potential extra pound of payload; but in rail service this is only indirectly true. Few conclusive data are available. While the direct cost of haulage can be calculated, the wear and tear on equipment, though known to be functions of weight and speed, are difficult of allocation. Some years ago an estimated cost of 5 cents per lb. per year

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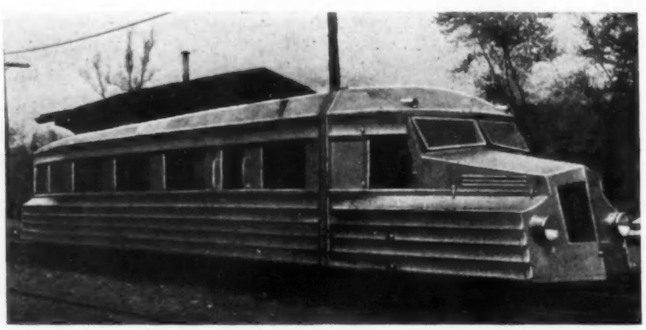


FIG. 7—THE LAFAYETTE, A VEHICLE ACCOMMODATING 24 PASSENGERS, WAS DESIGNED AND BUILT BY THE BUDD COMPANY FOR MICHELIN ET CIE, OF FRANCE

SOME PRINCIPLES OF LOW-COST TOOLING

By J. E. PADGETT

After predicting that the demand for changes in automotive products and the substitution of new devices will increase in the next few years and stating major factors with which managements are concerned at present, the author mentions that, after direct-labor costs, the next largest items of expense in a machine shop are generally depreciation and obsolescence of machines, fixtures and tools, especially when a plant is tooled for high production. He believes that the machine-tool industry might aid by reducing its prices and that this can be done, but that in such case the industry must eliminate its present cast-iron type of designing and many of its present manufacturing methods.

General machine-shop practice is analyzed and the illustrations show three classes of fixtures: (a) holding, (b) self-contained tools with holding means and (c) complete mechanisms. These show a new technic in obtaining fixtures cheaply, quickly and of such construction that they are capable of rapid, easy change. They illustrate the use of welded steel instead of cast iron and the principle of built-in accuracy.

INCREASING demand for changes in automotive products and the substitution of new devices will become evident within the next few years. Managements are concerned about (*a*) loss of sales if changes are not made; (*b*) excessive cost of tooling if changes are made, which cost may offset temporarily all of the gain in sales; (*c*) resistance of the shop organization to any change and (*d*) the difficulty of persuading the designing engineer to consider properly the problems of manufacture. Since such changes are coming in all successful companies, we in the manufacturing division must be ready to carry them through. Therefore I shall outline some of the principles that seem to be sound regarding the proper adaptation of tools, fixtures and equipment to meet these changes.

[This paper was presented at the 1933 Annual Meeting of the Society. The author is a Member of the Society and assistant general manager of the Spicer Mfg. Corp., Toledo.]

After direct-labor costs, the next largest items of expense in a machine shop are generally depreciation and obsolescence of machines, fixtures and tools. This is especially true when changes are taking place rapidly, and even more so when a plant is tooled for high production. The only way to reduce these charges is to make the machines last longer and thereby reduce the rapidity of obsolescence. We must at the same time keep up with the latest production methods. This procedure is antagonistic to the desires of the machine-tool builders, but the economics of the situation always govern in the end and, if new machine-tools are needed or if new developments of great value are made, these machine-tools will be purchased. If they are not needed, no amount of selling will cause purchasers to act.

I believe that the machine-tool industry could accomplish much if it would arrange to reduce its prices and that this can be done; but the industry will be obliged to get away from its present cast-iron type of designing and many of the present manufacturing methods. A very few machine-tool builders have already done a good job of this kind but this practice certainly is not general. Meanwhile, we in the manufacturing end should not demand unnecessary work or weight for the sake of appearance, and in this way the machine-tool builder can save cost. Further, the machine builder should be in the best position to make proper fixtures for use on his

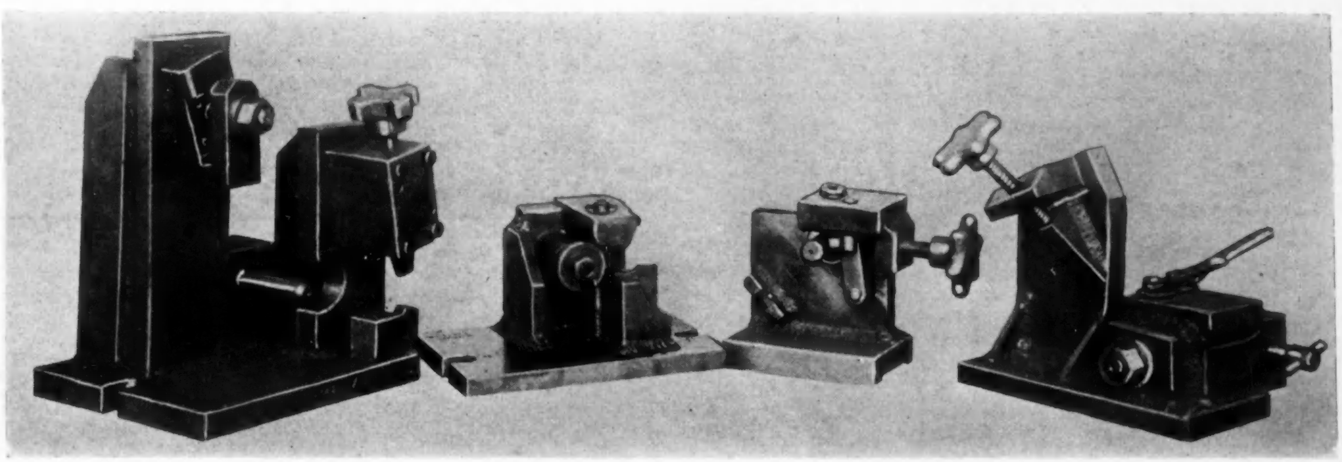
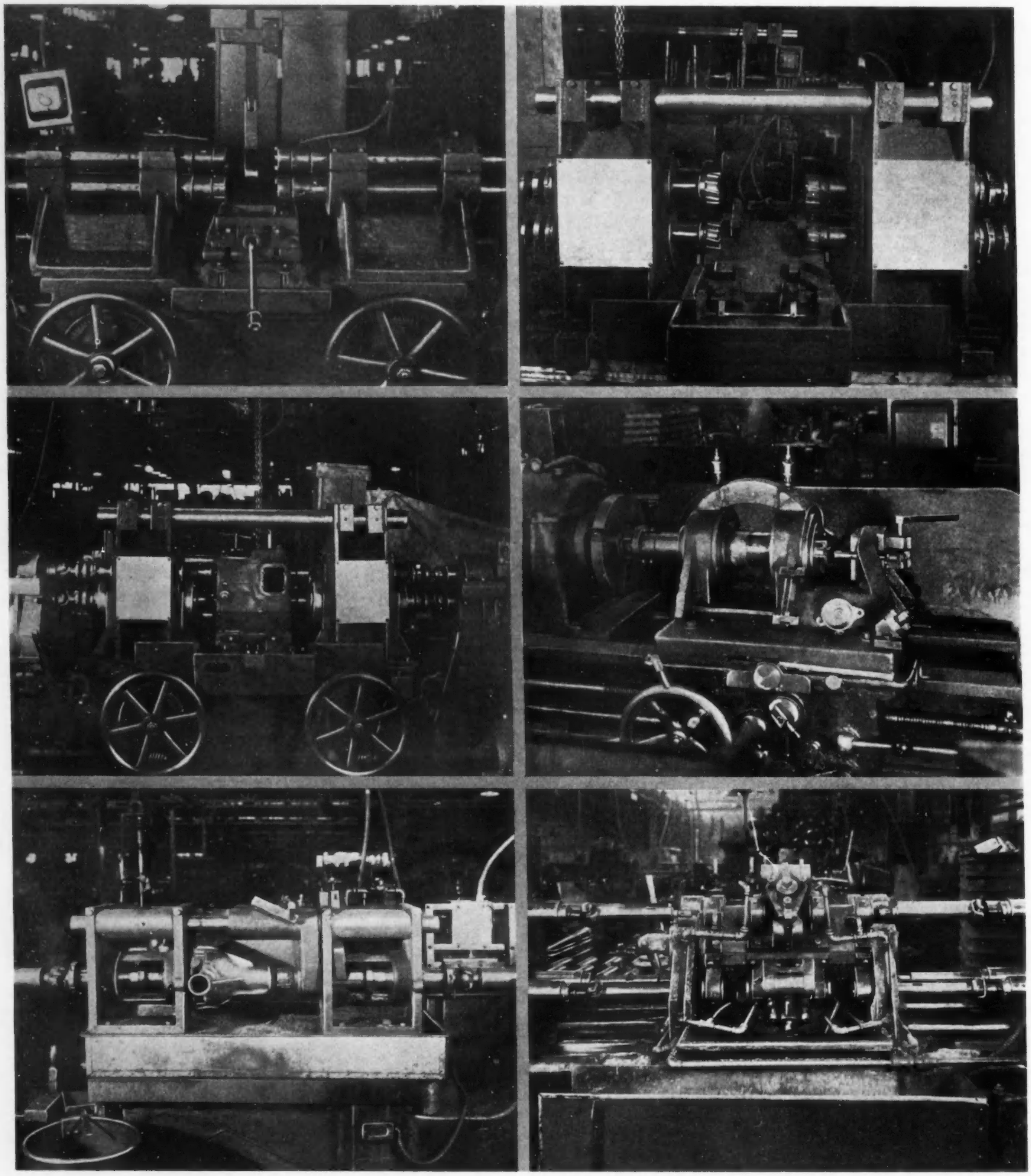


FIG. 1—A GROUP OF MISCELLANEOUS CLAMPING-TYPE FIXTURES



(a) A Former Method of Boring the Main-Shaft and Countershaft-Bearing Bores in Transmission Cases
(b) A Type of Fixture Now Replacing the One Shown in (a)
(c) How the Spindles in (b) Are Driven
(d) Another Self-Contained Fixture
(e) A Double-End Self-Contained Boring-Fixture for the Pinion-Bearing Bores of a Rear-Axle Housing
(f) Another Self-Contained Fixture, for Drilling, Boring and Reaming the Cross-Holes in Large-Size Universal-Joints

FIG. 2—EXAMPLES OF FIXTURES IN THE SECOND CLASSIFICATION

machines, but to get most of them to do a good job in this type of work seems impossible.

Machine-Shop Practice Criticized

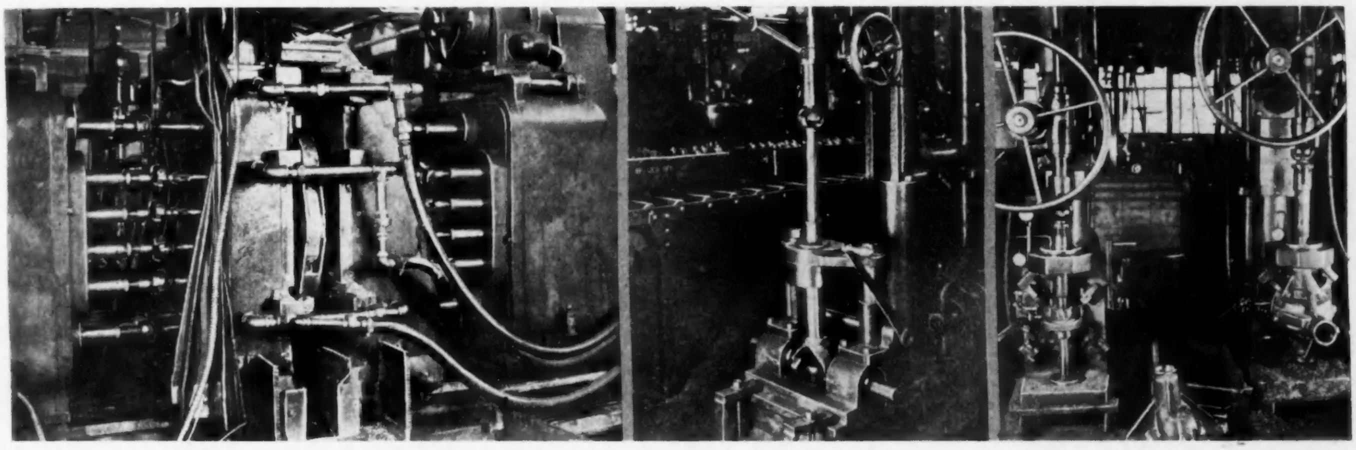
In a general consideration of machine-shop practice, we must decide on the correct place for simple single-spindle or single-operation types of equipment as compared with multiple-spindle multiple-operation machines. My experience is that the high-production multiple-tool machine seldom saves anything. Many cases can be mentioned where such machines are a positive saving; but in thousands of other cases they have been found to be a source of great expense and trouble, especially when a change must be made and the cost of re-tooling becomes excessive. To be economical these machines must be capable of running on a given job over a relatively long period, but seldom, in these days, does any product remain fixed in its design long enough to amortize the tooling. In addition, there is the larger percentage of down time, set-up time and various delays when any single unit gives trouble and stops the entire group of operations. I think I can best express my thought by referring to the banking business.

In general, we have two kinds of banks in this Country. One is a distinctly commercial bank which makes loans only on consumption goods in process of shipment or on the shelves for sale. This is done mostly on 30, 60 or 90-day paper, is backed by the credit of an individual or company and also is self-liquidating by the sale of these goods. Such materials are constantly selling, even in times of depression. If the judgment of the lender is good, the bank is practically 100 per cent liquid at all times. On the other hand is the investment-and-mortgage type of bank, in which the money is secured by bonds, stocks, mortgages and other long-term paper, where the judgment as to value is left almost entirely to some stock-exchange quotation. In a time of plenty such securities are easily salable; but in times of depression they become frozen, the value drops out and selling them or collecting the loans made with them as security is almost impossible. In boom times the investment bank makes excessive profits, while the commercial bank works on a narrow profit margin; but in a time of change and depression, the investment bank runs into excessive losses and in many instances actually closes its doors, whereas the commercial bank continues to operate steadily.

I feel that the highly special high-production multiple-operation equipment is like the investment type of banking, making large profits in boom times but becoming badly frozen and highly expensive in times of low production or rapid change. The simple machinery seems to be a little more costly during boom times; but, when adverse conditions come about, this equipment is good for almost anything and in any quantities, can be changed rapidly and at low cost, and over a long period is the safest and most profitable to use.

Tooling and Fixtures of Three Kinds

I shall confine my paper to the problem of tooling, and especially to fixtures of three kinds: first, fixtures that hold pieces while the piece is acted on by some self-contained machine; second, fixtures that not only hold the piece but are depended upon to give accuracy to the operation; third, fixtures that are really complete mechanisms in themselves. Typical fixtures are shown in the accompanying illustrations.



(a) Fixture in Which Accuracy of Work is Controlled Entirely by the Fact That the Fixture and the Machine Act Merely as a Driver Connected with Floating Universal-Joints

(b) Another Self-Contained Boring-Fixture

(c) Two Fixtures for Rough and Finish-Boring the Radial and Thrust Surfaces of the Differential-Bearing Bores in an Axle Housing

FIG. 3—OTHER EXAMPLES OF FIXTURES IN THE SECOND CLASSIFICATION

Fig. 1 shows a group of miscellaneous clamping-type fixtures. All are made up of pieces of scrap steel cut apart with an oxygen torch and welded together. These are built up from crude drawings and are very low in cost, especially if they are not duplicated many times. The steel is $2\frac{1}{2}$ times as rigid as cast iron and also is almost unbreakable in handling. If changes are desired, an acetylene torch and an arc-welding outfit are all that are necessary to cut them apart and rebuild them or to add new locating points or new clamps. This makes them extremely flexible and generally much lower in cost than the usual type of fixture made from patterns and castings. Another advantage is that they can be produced in an hour or two, whereas a casting always takes several days. Many times this advantage is highly useful in getting jobs done on time.

Figs. 2 to 5 show the second type of fixture, which has to do with accuracy as well as holding the piece. Fig. 2(a) shows a former method of boring the main-shaft and counter-shaft-bearing bores in transmission cases. This is a typical double-end machine having fixed centers and bars with wear

strips. The machine takes care of the accuracy of work, but the accuracy is not very good because the machine tends to spring, wear occurs in its different parts, and the floor may settle at some time. Such things are constantly happening to disturb the accuracy of the work.

Fixtures for Self-Contained Operation

The type of fixture in Figs. 2(b) and 2(c) now replaces that shown in Fig. 2(a). In this case, Fig. 2(b) shows that the entire operation is self-contained in the fixture. Each spindle is constructed so that it will slide inside of a quill, but a long feather key keeps the spindle from rotating relative to the quill. The quill is mounted in precision antifriction bearings and then this whole spindle unit is mounted in the fixture. The fixture is built of welded-steel sections and is completely tied together so that, when the piece is put in, the accuracy can be reproduced for many months without any change except to regrind and replace cutters.

Fig. 2(c) shows how the spindles in Fig. 2(b) are driven. The spindle itself is fastened to one side of a universal-joint and the other side of the joint is attached to the machine spindle. In this instance the entire set-up has four joints, made with clearance across the shoulders of the central cross so that they can take care of misalignment. Therefore the fixture itself cares for all questions of accuracy and the machine becomes merely a driver and feed mechanism.

This construction results in a fixture costing perhaps one-fifth of the machine cost and gives a better job than the original or a new machine. Further, if at some later date a change in the center distances becomes necessary, these spindle assemblies can be taken out, the fixture cut apart with the torch, some plates welded in, the fixture rebored on the new centers, a short propeller-shaft installed in place of single joints, and a new fixture obtained at a fraction of the cost of the original fixture or a new one that we would have to make if this were not of welded-steel construction. This type of construction allows us to use machinery as long as it will turn over.

Long Accuracy with no Repairs

Fig. 2(d) shows another self-contained fixture with antifriction bearings for finishing the inside of the reservoir of a vane-type shock-absorber. This operation was carried on for about a year, using fixtures lined up as well as possible with the machine spindles and with every care taken in material and up-keep of wear strips and bushings and with maximum precision-grinding on the counterbores. In spite of this, on a total of eight machines we kept two tool-makers continuously busy in maintaining the accuracy of the machines, and the set-up was excessive because only 1 out of 10 cutters would cut to size because of the combination of clearances and errors.

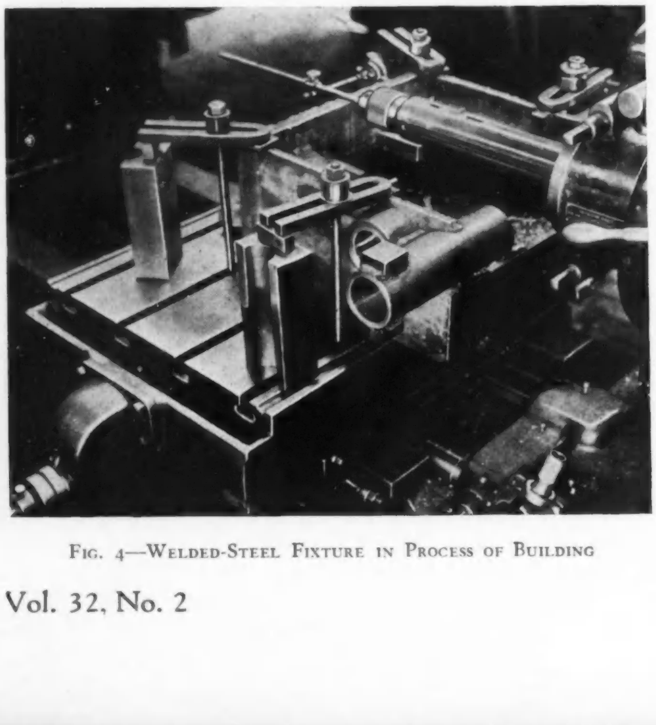


Fig. 4—Welded-Steel Fixture in Process of Building

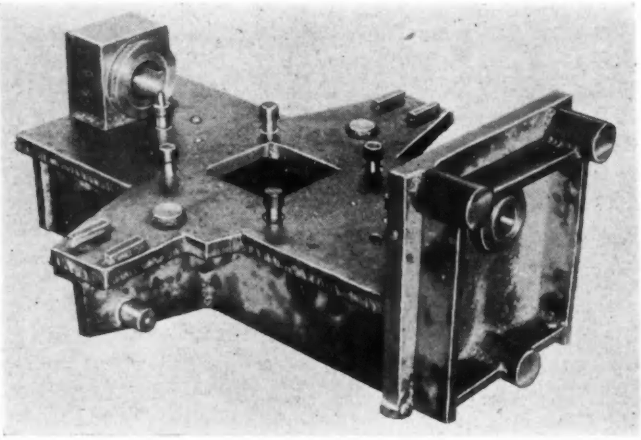


Fig. 5—Another Welded-Steel Fixture in Process of Building

After we installed the present antifriction-bearing self-contained fixture with universal-joint drive, no machine had to be repaired at any time because of trouble with accuracy in a period of three years, during which several million shock-absorbers were made. Now, after grinding, every cutter cuts to size; whereas, formerly, only 10 per cent cut accurately. One can realize the accuracy of this operation in that the piece has three concentric diameters that must be held to a 0.0005-in. limit in one instance and to a 0.001-in. limit in two other instances. The depth from the counterbored seat to the bottom must be held to a 0.0005-in. limit, the bottom must be absolutely square with the cylindrical portion and perfectly flat, no tool marks must show on either side or bottom and the corner where the surfaces meet must be square.

Floating Universal-Joints Control Accuracy

Fig. 2(e) shows a double-end self-contained boring-fixture for the pinion-bearing bores of a rear-axle housing. Fig. 2(f) illustrates another self-contained fixture for drilling, boring and reaming the cross-holes in large-size universal-joints.

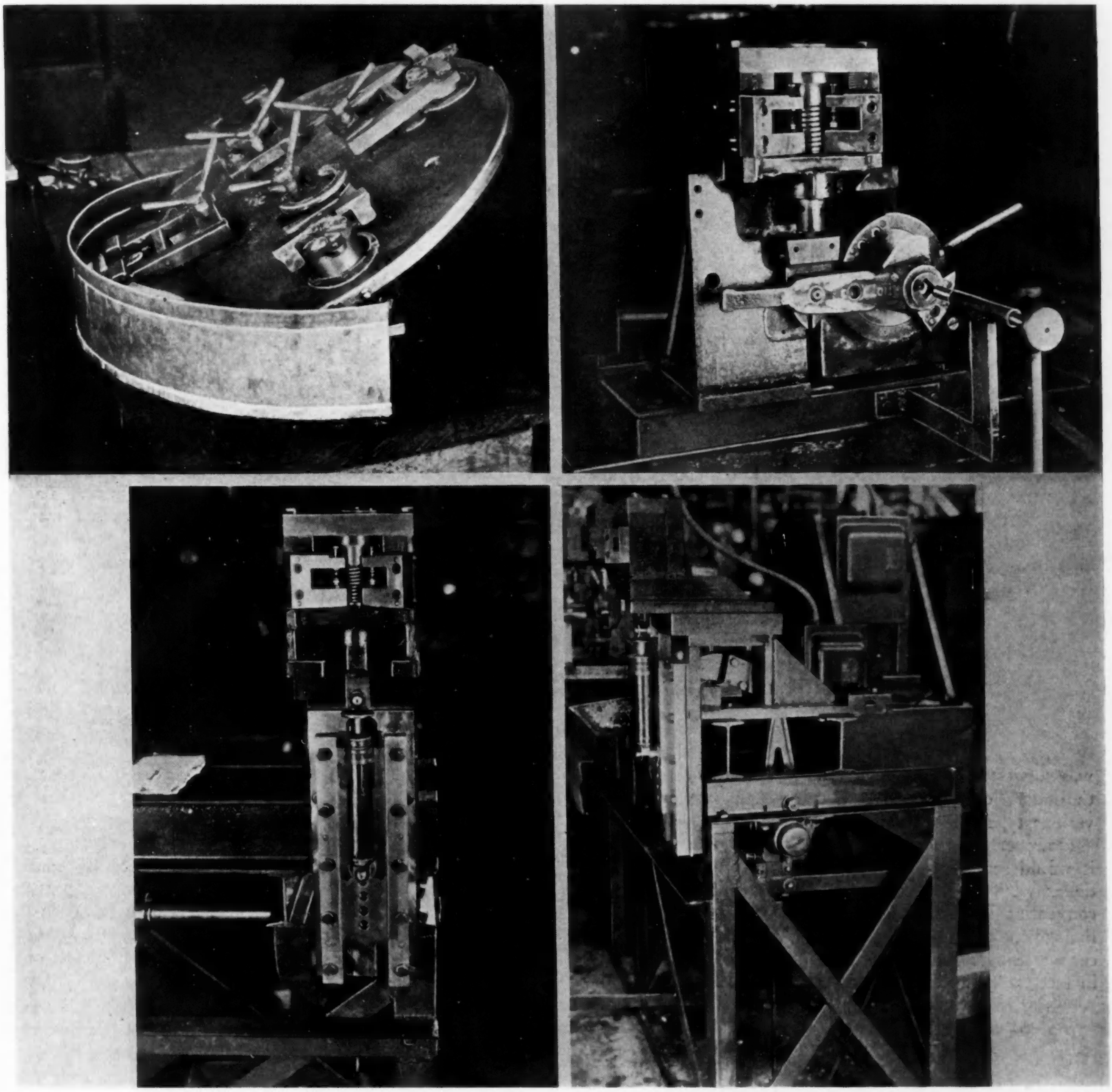
The multiple-spindle drilling-and-boring machine shown in Fig. 3(a) is another case in which the accuracy is controlled entirely by the fact that the fixture and the machine act merely as a driver connected with floating universal-joints, a principle of fixture construction that we began to develop about four years ago. After searching high and low for a good floating drive without success, we finally found, right under our nose, that for taking care of this condition we had a suitable mechanism in the universal-joints that we supply as an every-day product. These must be adapted to the machine, but this is a simple and inexpensive process.

Fig. 3(b) shows another self-contained boring fixture. Fig. 3(c) illustrates two fixtures for rough and finish-boring the radial and thrust surfaces of the differential-bearing bores in an axle housing. Figs. 4 and 5 show welded-steel fixtures in the process of building.

Figs. 6(a) and 6(b) show self-contained mechanisms. The former is a water-test fixture for testing the porosity of shock-absorber bodies with air pressure. It is composed of a piece of boiler plate, some welded clamps and clamp screws.

Fig. 6(b) is a fixture for testing shock-absorbers for resistance at car-operating speeds. In this instance we learned very strikingly the usefulness of the welded construction. The operation is to oscillate the shock-absorber at about 100 strokes per min. and to indicate that the resistance is between specified limits. This is shown by checking the amount of movement of a calibrated spring and recording this by having it light a green lamp for "satisfactory" and a red lamp for "unsatisfactory."

We first built this in one design that developed trouble due to friction in various parts of the mechanism. The friction caused a change in the registered resistance on the spring, and the fixture had to be so sensitive that this friction made the whole operation useless. In efforts to eliminate this friction, we changed and rebuilt parts of this machine about a dozen times. We also had trouble with the electrical con-



(a) A Water-Test Fixture for Testing the Porosity of Shock-Absorber Bodies with Air Pressure
(b) A Fixture for Testing Shock-Absorbers for Resistance at Car-Operating Speeds
(c) and (d) Fixture Shown in (b) as Rebuilt To Make It Applicable to a Newly Designed Shock-Absorber

FIG. 6—THIRD-CLASSIFICATION MECHANISMS

tacts, which had to be accurate within 0.001 in., and this part of the mechanism also was rebuilt about a dozen times.

Steel Construction Facilitated Quick Changes

We had only about 10 days in which to attain high production. During these various changes and testing, we worked tool-makers constantly day and night trying one thing after another until the machine was worked out so that it was satisfactory as we made each change. Because it is of steel construction we were able to cut off parts that were wrong, machine the piece, weld on some new piece and develop it for the next trial so that it would be ready to try out within say 3 hr. If this had been of the ordinary construction requiring patterns and castings, to go through with the amount of development work would have taken us three months, and we would have been sadly out of the running in getting into production.

We have again changed the design of shock-absorber and Figs. 6(c) and 6(d) show the Fig. 6(b) testing machine rebuilt once more to take care of the new product. Most of the old parts were used even though the new design of shock-absorber is entirely different. This would have been impossible with ordinary fixtures made of cast iron. This change was made without using drawings; the tool-room supervisor simply was told what was wanted and this was carried out.

In conclusion, a condition exists of which I have heard several engineers talk in no uncertain terms. It relates to the question of what they have to do when trying to crowd a certain number of cubic inches of displacement into an engine having given center distances for the cylinders when the plant equipment cannot be changed to a different set of center distances.

My thought would be to make self-contained fixtures for the individual cylinder bores, tie these together into the correct distances between centers, raise the present fixed-head boring equipment by a riser block and connect the present spindles with propeller-shafts to the new self-contained spindles. I believe that, for a cost only slightly more than that of a new fixture, one could thus have newly changed boring equipment. Further, if any changes were desired later, they would require only new spacer bars for the individual fixtures. If other fixtures in the cylinder-block line took their locations from the cylinder bores and if these fixtures were made from steel, it would be a simple matter to cut out the old locating points, weld in new parts and re-machine to fit any necessary changed condition.

I hope that I have been able to present some useful thoughts on tooling problems that will help to reduce the cost and increase the flexibility of operation, because I am certain that we shall need to prepare for numerous and rapid changes during the next five years.

THE MECHANICS OF RECOVERY

(Concluded from p. 53)

wages, salaries or profits. In this analysis, business comprises all gainful occupations (except clipping coupons) so to speak; all the activities through which goods and services are produced and wealth or earnings allocated to the different members of society. Thus, capital goods on the one hand and business on the other comprise the entire economic set-up, including the production of social capital. The latter, when once produced, drops out of consideration because, as social capital alone, it has no direct economic reactions. To be sure, social capital is of utmost social importance and, insofar as it requires goods or services for maintenance and what not, it contributes to business. Solely as social capital, however, by our definition, it does not draw interest, therefore places no continuous burden on business.

WHY AND HOW OF RUBBER-TIRED RAIL-COACHES

(Concluded from p. 58)

was suggested. This still stands in the absence of more authoritative evidence, though subject to interpretation for various types of service.

However, 5 cents represents the yearly interest on $1, and it would seem that every pound saved at the expense of a dollar would be self-sustaining. The average unit cost of conventional self-propelled rail-vehicles is about 40 cents per lb., which, for a 100,000-lb. car, is $40,000. An equivalent car weighing 25,000 lb. might then cost $75,000 more. But in fact the cost of the lighter vehicle runs about the same as that of the heavier one. It follows then that its operation alone should show a net saving of $3,750 per year; that is, 75,000 lb. of weight saved at 5 cents per lb.

However subject to criticism these specific figures may be, the line of thought is properly one for engineering consideration. Economy is, after all, the goal of engineering attainment. It is the only justification of change. It has been the guiding spirit behind the Budd venture in rail transportation, and the means whereby it is realized become of interest only in the extent to which they succeed.

ON ELECTRIC-FURNACE CAST-IRON

As an Aid to Designer and Foundryman

Three papers presented at the Passenger-Car-Activity Session of the Detroit Section meeting held Nov. 7, 1932, are published herewith. The paper by H. T. Woolson expresses the designing engineer's viewpoint; those by A. E. Hageboeck and W. R. Jennings, the foundryman's viewpoint.

THE DESIGNER'S VIEWPOINT

By H. T. Woolson[1]

Mr. Woolson points out that designers are continually trying to make 1 lb. do the work of 2 lb. but are prone to underestimate the important possibilities of alloyed cast iron in automotive engineering. Recent improvements in methods of handling molten metal for casting lends these methods to the obtaining of uniformity of castings and physical properties. Some readily obtainable properties of electric-furnace iron are strength approximately double that of ordinary cast iron, increased wear resistance, reduced growth characteristics, heat resistance and corrosion resistance.

In considering the use of high-strength cast-iron and other specific alloys of iron produced by the electric-furnace process from the designing engineer's viewpoint, it has been deemed desirable to approach the subject from a fundamental basis of engineering design.

The importance of lightness in weight of mechanism takes prominence in the automotive industry perhaps more than in any other, a fact which may be the key to the remarkable engineering advances in this industry. In exaggerated terms, designers are continuously trying to make 1 lb. do the work of 2 lb. It is necessary only to glance over the history of the last 25 years to observe what has been accomplished; for instance, in aircraft construction, weight consideration predominates. The very life of aircraft structures depends upon lightness, and this is true in a lesser degree with the automobile. Automotive engineers have much to learn from their aircraft brothers along the lines of using materials to the best advantage, although they are not convinced that four wheels placed under a fuselage will produce an acceptable car.

Weight saving in design is a very intriguing thought. Mechanisms of today contain many lazy pounds that do not contribute to structural strength to the limit of their ability. An I-beam or channel always carries lazy pounds along its neutral axis; shafts carry useless weight in their center section. We find material capable of safe stresses of 50,000 lb. per sq. in. being used to carry 5000 lb. per sq. in. or less.

All engineers are familiar with instances in which slight additions of insignificant amounts of material for fillets, the reshaping of sections or the addition of ribs, result in strength increases of 25 to 50 per cent. Conversely, the removal of slight amounts of material at critical points may destroy structural strength. Therefore, one of the chief functions of the successful designing engineer can be defined as the ability, by the practice of engineering principles, to weave into designs the correct materials in such a way as to make the maximum amount of these materials work up to the limit of their safe physical capacity.

A limit, however, is placed on the engineer's efforts when he has designed to the limit of available materials. He may then, as often happens, be left with a longing for a yet unborn material specification which shall fulfill certain desired characteristics. What automotive engineer has not wished for a material as light as aluminum and having the expansion characteristics of cast iron?

The fraternity of designing engineers may well take off their hats to the metallurgical engineers who have cooperated with them in such a gratifying way for many years to provide desired material characteristics as requirements developed. During the last three decades the automotive-industry metallurgists have striven to meet these requirements, the most outstanding of their accomplishments being the development of alloy steels and methods of heat-treating, with resultant wonderful physical properties. Were it not for these accomplishments, our vehicles today would be heavy and ponderous.

Automotive Importance of Cast Iron

In this age of steel we are prone to underestimate the important position occupied by cast iron in automotive engineering. Alloy steels, with their high elastic and ultimate tensile strength and other desirable characteristics, have appeared to hold the stage as being more dramatic than cast iron, which we may characterize as the plodding workhorse. Members of the Society may be partly responsible for neglecting this most valuable material, because the Society's Iron

TABLE 1—DISTRIBUTION OF MATERIALS IN A CAR

	Lb.	Per Cent
Steel, stamped and rolled	1,475	47.5
Steel, forgings	425	14.0
Cast Iron	460	15.0
Malleable Iron	125	4.0
Non-ferrous Metals	150	5.0
Wood	65	2.0
Glass	70	2.5
Trim and Deck Material	100	3.0
Rubber, compounded	165	5.0
Lacquer and Enamels	25	1.0
Miscellaneous	30	1.0
Shipping Weight	3,090	100.0

[These papers constitute a symposium presented at a meeting of the Passenger-Car Activity of the Detroit Section.]

[1] M.S.A.E.—Chief engineer, Chrysler Corp., Detroit.

and Steel Specifications do not include specifications for gray-iron castings; but, it may be added, the various automotive-engineering departments have formulated their own specifications.

That cast iron is an extremely important material in the automotive industry is evident from Table 1, which shows the distribution of the various materials in a Dodge six-cylinder Model-DL sedan and proves that the weight of cast iron in the average car exceeds the weight of steel forgings.

The more commonplace material, cast iron, is just one step away from the blast furnace, but steel in bar form as we purchase it represents many steps. Cast iron has existed for years with little or no progress toward improving its characteristics. Recently, however, since the introduction of the electric furnace, which was originally brought out for another purpose, the metallurgist has been furnished a more exact tool with which to work and designers can testify that they are taking full advantage of this tool.

Electric-Furnace Iron Represents a Process

Electric-furnace iron is descriptive of a process and does not describe a product. The product of the electric furnace may be no better than that of the cupola; conversely, the cupola product may be equal in every way to that of the electric furnace. But the viewpoint of the engineer is that the more recent development of improved methods of handling molten metal to be used for casting purposes lends itself to obtaining a uniformity of castings and physical properties very much desired by the designing engineer, though naturally he is interested mainly in the quality of the product regardless of the method by which the result is obtained.

We are inclined to believe that the more modern methods are setting up standards which will result in improving the standards for castings of all descriptions, regardless of how produced. Automotive engineering is becoming more and more an exact science; research and investigation have removed many of the mysteries which existed some years ago. This reacts on design in tending toward the lightening of structures, because, with a more correct understanding of forces and the possession of more uniform material having more desirable physical characteristics held to closer limits, it is possible to reduce factors of safety, or factors of ignorance as they are sometimes called. It is safe to predict that further metallurgical progress in the development of alloy irons will result in placing in the designers' hands materials making for still lighter construction.

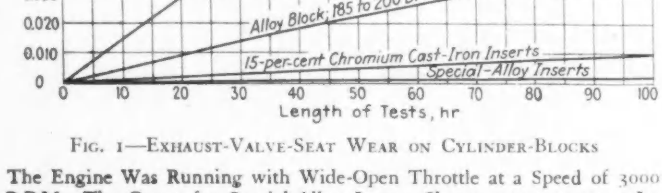


FIG. 1—EXHAUST-VALVE-SEAT WEAR ON CYLINDER-BLOCKS

The Engine Was Running with Wide-Open Throttle at a Speed of 3000 R.P.M. The Curve for Special-Alloy Inserts Shows 0.000 to 0.002-In. Wear for a 100-Hr. Test

The introduction of the electric furnace in the production of castings has resulted in furnishing the designer high-strength iron, a uniform product and the possibility of variations in iron specifications to meet requirements in various specific cases. Some of the improved properties in iron made readily attainable are (*a*) available strength approximately double that of ordinary cast iron; (*b*) increased wear resistance; (*c*) reduced growth characteristics; (*d*) heat resistance; and (*e*) corrosion resistance.

Current Applications of Alloy Iron

Let us now consider some of the current applications of alloy iron. One of the most interesting instances is that of the development of improved cylinder-block iron. Some years ago, as the result of obtaining higher engine outputs per cubic inch and increased engine speeds, it was observed throughout the industry that exhaust-valve seats were not standing up sufficiently well to be entirely satisfactory from a service viewpoint. Designers endeavored to better conditions by the use of wider valve seats, better water circulation and other means, with some degree of success, but leaving much to be desired. At this point the metallurgist came to the rescue and, by using an alloy consisting of 0.50 to 0.80 per cent nickel and 0.10 to 0.20 per cent chromium, a harder casting having a Brinell hardness of 185 to 200 was obtained, capable of twice the endurance to valve pounding. This iron supplied other advantages such as improved bore-wear characteristics, less cylinder cracking and less machining scrap.

On a later engine design the foregoing alloy was found not to be good enough due to attaining still higher engine output, making necessary the use of a mixture containing 1.50 to 2.00 per cent nickel and 0.40 to 0.60 per cent chromium, with a Brinell hardness of 210 to 240 and just within machining limits. This proved satisfactory for passenger-car work and once more special-alloy iron saved the day. Later, the severe requirements of truck engines necessitated still further study of the exhaust-valve situation. This resulted in the development of a high-speed tool-steel valve-seat that gave entire freedom from valve trouble, even for truck-engine service. This valve-seat material was soon replaced by an alloy-iron seat of special analysis having a Rockwell C hardness of 50-60, a mixture possessing the qualities of red hardness to a high degree. This alloy also had the same approximate coefficient of expansion as the block. As a result of this latest development, it has been possible to drop back again to a lower cylinder-block alloy having better machinability. The remarkable results obtained with valve-seat inserts has led to their adoption for cars in the lowest-price class.

A Series of Tests Made

In connection with the development work on valve-seat wear, a large number of tests were made with wide-open throttle at a speed of 3000 r.p.m., the engines being operated continuously for 100 hr. except for short intervals every 10 hr. to measure tappet clearances. Tests were made using gray-iron blocks of low hardness, 150 to 160 Brinell; alloy blocks of 185 to 200 Brinell hardness; blocks with 15-per cent chromium-cast-iron inserts; and, finally, with alloy-iron inserts. The relative wear of exhaust-valve seats at the end

of a 100-hr. run were 0.130, 0.043, 0.010 and 0.002 in. Further tests were made up to 300 hr. with alloy-iron inserts, resulting in a very slight increase and showing clearances of 0.003 in. This is believed to be an outstanding example of what can be accomplished with the proper selection of material and reflects great credit on metallurgical investigation that has been responsible for producing such materials.

Fig. 1 is a chart showing exhaust-valve-seat wear on cylinder blocks of various alloys and on valve-seat inserts. It is noted that the wear in all cases except those of the special-alloy inserts is practically on a straight-line basis; whereas, with special-alloy inserts, the curve flattens out after 90 hr. of running and from there on the wear is practically eliminated.

Special-Alloy Iron Applications

Another major use of special-alloy iron on modern cars is for brake-drums, a development that was forced on the industry by higher road speeds and the general use of such devices as free-wheeling, automatic clutches and vacuum-controlled brakes. This subject has been so completely covered in various presentations that it is unnecessary to go into detail. Further uses of special irons having specific qualities can be listed, such as exhaust manifolds to resist cracking, valve-stem guides and heat-control valves of Ni-resist iron to resist growth; also, piston-rings for uniformity and fineness of grain. All are capable of being produced by several processes.

In view of the many and varied iron alloys in use in the automotive industry and the certainty of further progress, it behooves designing engineers to familiarize themselves with some of the remarkable metallurgical accomplishments that are being made today. Future advances in metallurgy may make possible the safe production of camshafts and crankshafts by casting methods; in fact, there is today some production of cast camshafts. Such developments are welcomed by the engineer, provided they are accompanied by real advantages. An engineering advantage in connection with the more modern methods for producing castings is the possibility of pouring iron at a higher temperature, thus tending toward lighter sections and more intricate shapes.

As I have taken as a general theme structural lightness and efficiency in the use of materials, I shall predict that, in the near future, the metallurgist will make it possible for designers to make further strides in this direction by continued developments, producing specifications to meet the engineers' more and more exacting requirements and using tools and equipment best fitting the particular case in hand, with resulting advantages to motor-vehicles of lower first cost and maintenance and improved performance due to weight saving.

APPLICATION TO MOTOR-VEHICLES

By A. E. Hageboeck[2]

Mr. Hageboeck deals with the application of cast iron made by the electric-furnace process to automobiles, motor-trucks and motorcoaches and states that, as supplementary to the cupola method, the electric-furnace process, with its greater flexibility, higher temperature and close control, opens up to the gray-iron foundryman a field that would not otherwise be possible. Almost any composition desired can be made by the process and, as small quantities can be produced economically, the designing engineer can obtain almost any kind of a mixture and pour it in regular-production molds for sample purposes to try out new ideas.

To my mind the relation of the electric furnace to the cupola is exactly the same as that of the street-car to all other modern methods of transportation. We always will have street-cars because, under certain conditions, this kind of transportation probably always will be more satisfactory and the most economical. Similarly, under certain conditions, we always will find the cupola satisfactory and decidedly more economical; but, for the better grades of high-strength irons, the electric furnace offers greater possibilities.

In this paper the application of electric-furnace cast-iron to automobiles, buses and trucks will be presented.

Today's automotive foundry exhibits an increasingly satisfactory metallurgical control of cupola operations. Fairly uniform composition can be maintained to produce at high temperatures irons of high strength, wear and heat-resisting properties. In our march of progress to produce still better irons, the electric furnace offers greater flexibility, still higher temperatures and a closer degree of metallurgical control.

Comparing the progress made in the last 20 years in cupola operations with that of the electric furnace, in the early days it was not uncommon to have what was called a "bum" heat, the term usually being applied to days when for some unknown reason the cupola was not making satisfactory metal. The foreman often would explain that "we had bad-luck today; the iron melted hot but had no life and, as a result, we had a lot of cold shot. Even the castings we did pour probably will have blow-holes after machining."

In many cases the thought was prevalent that this was simply a condition of cupola operation that could not be corrected. Since then many automotive foundries have standardized their raw materials and operations, surrounding the entire process with laboratory and metallurgical control to the end that many of these foundries today are making a very satisfactory product and are holding a very uniform control of the composition.

But it is recognized that there are certain limitations with the cupola, and it seems to us that the electric furnace opens up to the gray-iron foundryman a field that would not be possible were it not for the advantages that can be gained by the use of the electric furnace, always recognizing the fact that the cupola is perfectly satisfactory for certain classes of work. Therefore, the electric furnace will supplement but will not replace the cupola.

Flexible Control Analyzed

Six major points are noted regarding the flexibility of the electric furnace; first, *it kills an alibi.* There is always someone in the organization who has an idea that if the total carbon could be lowered 25 points all troubles would be eliminated. This is impossible where the basic mix coming from the cupola has been standardized to conform to a wide variety of specifications. The total carbon in this basic mix having been standardized, it would be exceedingly difficult to comply with this change unless a sufficient tonnage was ordered that would warrant such a major deviation from standards. The present status is that almost any composition that is suggested can be made in an electric furnace, and that any theory advanced can be proved or disproved.

[2]President, Frank Foundries Corp., Moline, Ill.

The second advantage is that *it gives the designing engineer an opportunity to try out his ideas*, with very little trouble. Many times an engineer would like to have some variation in the composition that is difficult to make in small quantities in the cupola. Here the electric furnace is of wonderful help; now, practically any kind of a mixture can be made and poured in regular production castings for sample purposes.

What has been termed *a stepping stone* is a third advantage; that is, an electric furnace enables the development of some of one's own ideas. Then, in the final analysis, these new mixtures can be made profitably in the cupola after the new composition has been tried out and a sufficient tonnage is ordered to warrant a cupola heat.

Fourth, under the heading of *metallurgical research*, an unlimited field is possible for proving or disproving certain theories that were difficult to try out in the cupola for the reasons already stated.

Fifth, *a very definite service advantage* is that very often we are asked to make a service part for replacements. Perhaps the part has been out of production for several years, none of the present standard cupola mixes complies with the old specifications, and it would be exceedingly difficult to make up a small order. But with the electric furnace it is easy to make up whatever quantity is needed for any such special orders.

Sixth, as to *new products and new uses*, the electric furnace is enlarging the scope of the gray-iron foundryman's work in that there are many uses where gray cast iron has qualities superior to those of materials now being used; yet, for very definite reasons, engineers were reluctant to specify cast iron because of lack of uniformity of composition or some other important factor. With the higher temperature and better control afforded by the electric furnace, many new products will be developed to the mutual benefit of the public, the designing engineers and the gray-iron foundrymen.

AUTOMOTIVE - FOUNDRY CLASSIFICATION

By W. R. Jennings[3]

Mr. Jennings describes a test now being considered for determining the point of optimum superheat for lifting iron from a static to a dynamic condition, with tensile strength of alloyed cast iron of 80,000 lb. per sq. in. and of heat-treated iron of 100,000 lb. per sq. in. When this field is entered, increased temperature becomes necessary for consistent results, and a series of tests is being run to discover approximately the temperature at which breakdown of the carbon nucleus occurs. The electric furnace, Mr. Jennings asserts, offers a non-oxidizing and non-contaminating method of melting iron at any desired temperature and allows iron to become high-brow and choosy.

A renaissance in the gray-iron industry is being experienced today. The very fact that this session has been devoted to so humble a material as iron castings shows that, under the tutelage of Moldenke, MacKenzie, Bornstein, Bolton and others in this Country, and that of many foreign investigators, foundry engineers have lifted iron from a static to a dynamic status. The concentration of so many active minds on the improvement of cast iron has increased its tensile strength from 18,000 to 25,000 lb. per sq. in. to 45,000 lb. without and up to 80,000 lb. with alloys, or even to 100,000 lb. per sq. in. with heat-treatment.

[3] Manager, Frank Foundries Corp., Moline, Ill.

Good high-strength iron, alloyed and unalloyed, is being produced in the cupola in ever-increasing quantities. We then ask, What does the electric furnace offer to the gray-iron foundryman who operates only a cupola? Primarily, it offers three things: (*a*) flexibility; (*b*) an additional temperature when this is desirable; and (*c*) better control of analysis.

Foundries can be classified as those having exceptionally good melting practice and producing iron at 2800 deg. fahr. and over, those having an average practice which produce irons at 2600 to 2800 deg. fahr. and those of questionable practice which melt their iron at 2500 to 2600 deg. fahr. Cast iron melts at approximately 2250 deg. and freezes at approximately 2100 deg. fahr. Normally, we expect a loss of 150 to 400 deg. fahr. from the time the iron leaves the cupola until it is poured; therefore an iron melted at 2500 deg. averages 200 deg. above the freezing point when it is poured into the mold.

As compared with the cupola, the electric furnace offers a new range of temperatures of from 2900 to 3100 deg. fahr.; and thus the range of melting temperatures has been advanced approximately 200 deg. above the best range of cupola practice. The ordinary gray iron does not cause undue trouble in the cupola, with good melting practice. It is only when we enter the field of high-strength iron, iron of special analyses such as low-phosphorus, low-carbon or high-alloy mixes, that the need for increased temperature becomes not only desired but necessary to consistent practice. We will not argue the point of when superheat is attained and whether it is attained at 2600, 2750 or 2900 deg. fahr.

Electric-Furnace Irons Tested

Our company is making a series of tests of electric-furnace irons, of the same analyses, melted and poured at various points as indicated. We hope to discover from microphotographs approximately at what temperature the breakdown of the carbon nucleus occurs. If the theory of the destruction of the carbon nucleus is correct, we have thus far been unable to find anything but theory in regard to this definite point. But, as practical foundrymen, we know that the greater percentage of miss-runs, cold shots, shrinks and generally dirty castings is due to cold metal; that hot metal gives a more solid casting than when poured only a few degrees above the freezing point, as well as a better appearance; that this hot iron is considerably stronger; and that heads and risers can be made much smaller with this type of metal if it is poured into proper-sized gates.

A sample cylinder casting was poured at high temperature to indicate the possibility of reducing the gate area. It was poured at 2950 deg. fahr., the total carbon content being about 2.70. The iron was designed for a ½-in.-section header casting, which is normally tested at 500 lb. per sq. in. hydrostatic pressure. The cylinder, as poured, was 5½ in. in diameter, 16½ in. long and the gate area was 5/16 in. in diameter. As already mentioned, this metal was not designed for this casting; we poured it into this specimen form simply to see what this particular metal would do in a 5½-in. as compared with the ½-in. section for which it was designed. The gate or sprue of this casting has a Brinell-

hardness number of 248, which is the same as we found at various points on the castings themselves. The indicated hardness across the face of this cylinder is 248, 255, 255, 241, 248, 241, 255 and 255.

We do not cite this case as being particularly ideal, because this metal was not designed for a 5½-in. section, but it does show the influence of pouring at high temperature and of using the reduced gate-area to overcome the necessity for excessive feeders and risers. The feed end of this casting was reduced to the minimum. We believe that this is one of the very important advantages that the electric furnace offers to the gray-iron foundryman; that is, the increased temperature so that the metal can be gated and handled as he desires.

Control is the third and very important item in favor of the electric furnace. By the very nature of the cupola, the metal comes directly into contact with the fuel. The results obtained are contingent upon the original mixture of the pig iron, the amount of steel scrap used, the amount and the analysis of coke used, the depth of the bed, the blast pressure, the volume of air, the height of the charging door, whether the furnace is operating with a hot or a cold blast, whether the coke is dense or porous, and many other conditions which enter into the making of good cupola iron. The good control that automotive foundries are able to maintain in spite of these conditions is surprising.

Our company prides itself on making a good high-strength iron, the temperature of the metal at the spout, as checked by the Bureau of Standards, being 2875 deg. fahr. Carbon content is controlled within a variation of 15 points. With a 2875-deg. temperature at the spout, we believe that we can safely assume a 3000-deg. temperature in the melting zone; that is, we have "hot iron" or superheat. Further, we are not unacquainted with the use of molybdenum. This control feature of the electric furnace is one which the gray-iron foundryman greatly appreciates. Since the metal in a cupola is in direct contact with the fuel, it is subjected to blasts of air which, with a slight misworking of the cupola, become oxidizing blasts. In fact, they absorb certain elements in contact with their close neighbors such as sulphur, carbon and certain debatable gases that are not within the scope of this paper. On the contrary, the electric furnace offers a non-oxidizing and non-contaminating method of melting iron at any desired temperature.

Automotive Engineers Credited

Automotive engineers have been very charitable in their chemical specifications to the foundry. They have made the range of silicon, carbon and the like very broad. They have given foundrymen, as they have given themselves, a very reasonable margin as a "factor of ignorance." But the electric furnace changes this and offers to the engineer a melting unit for obtaining in the foundry what he theretofore was able to get only in the laboratory. If the engineer knows what he wants, which the average foundryman sometimes questions, the electric furnace will provide it for him. The range of silicon, carbon, sulphur, phosphorous and the like can be controlled at will. It is important that the engineer should name what he wants if he knows what he wants.

A great amount of work has been done in regard to improving electric-furnace iron; on the other hand, we have much to learn. The fact remains that the foundryman can obtain what he wants from the predetermined analysis given by the electric furnace. Better physical analyses are obtained and it is therefore not unreasonable to say that high-strength irons are tough; but carboloy was placed on the market at just about the same time that electric-furnace superheated irons were. At least, we have them both now, with the reservation that, if one does require different machining speeds than would seem to be indicated from this statement, use of the annealing furnace will give just about whatever gradation one requires and, provided proper chemical analyses are maintained, still maintain high strength. One can reject the undesirable and retain the desirable elements.

Electric Furnace Beats the Cupola

An application of an iron which was impossible to make in the cupola but was made readily in the electric furnace is now cited. By retaining the usual percentages of silicon and carbon but reducing the phosphorous content from 0.20 to 0.02, the sulphur from 0.07 to a mere trace, and making a moderate use of alloys, we have produced a high-strength cast iron having a 3.25 total carbon content and a tensile strength of 66,000 to 70,000 lb. per sq. in. as cast. The engineers in this particular application were faced with the problem of excessive wear; they had been using aluminum bronze and manganese bronze, but these parts wore very rapidly. They asked for a material that would have both a high carbon content and a high tensile strength. This material was produced, and the engineer's report of how it actually performed is available. Suffice it to say, this iron out-wore the other materials on this application by a considerable margin. The Detroit Testing Laboratory analyzed this iron. After testing the samples, it requested more samples immediately, so that it could rerun the phosphorous and sulphur analyses; for, as was stated, there surely must be some mistake because iron ordinarily was not made that way. However, we gave assurance that this was quite all right.

Physical Properties Desired by Foundrymen

In the discussion of his paper on The Correlation of Mechanical Tests for Cast Iron[4], J. G. Pearce said: "If we are going to measure the quality of cast iron by mechanical test, let the buyer's specification be on mechanical tests, and let him not tie our hands by chemical analyses . . . We can get a given effect today with several different analyses, if we want it. It is purely a question of manipulation in the shop . . . Strength is governed by structure and that is not entirely controlled by analysis."

Especially is this applicable with the new irons of today, which have such radical differences in strength as compared with the standards accepted heretofore. Even in this connection, we might refer again to cupola practice.

Mr. Pearce also quoted[5] from J. T. MacKenzie's paper entitled The Properties of Coke Affecting the Cupola Melting of Steel that "irrespective of the total carbon content of the original charges, a given melting furnace tends to produce—and on sufficiently repeated melting will produce—a total carbon content peculiar to the furnace."

Some specifications today, for instance, contain a note "use 25-per cent of steel" when, under certain cupola operations, 20 per cent of steel would give the desired result, or even possibly less; for, when one realizes that the distribution of graphite is the important factor in gray iron and that this

[4]See *Transactions of the American Foundrymen's Association*, vol. 38 [1930], pp. 718-719.

[5]See *Transactions of the American Foundrymen's Association*, vol. 38 [1930], p. 685.

is controlled by the melting condition peculiar to that particular foundry, the definite chemical specifications cannot always brings out the definite physical requirements for which the engineer has asked.

I quite agree with Mr. Pearce, but also hasten to add that it will be a happy day when the foundryman can do either consistently, and this is being brought measurably nearer by the electric furnace.

The electric furnace, from the viewpoint of a gray-iron foundryman, does three things well: it provides flexibility, additional temperature as rquired and better metallurgical control. It is a means, not an end, toward better irons.

STABILIZATION AND STAGNATION

THE railroad industry decided a number of years ago, with the able assistance of the Government, that it was finally complete. Things were established; research was stopped; new ideas, other than in detail engineering, were discouraged; schedules, materials, dimensions, rates and competition were all standardized. As a result, the railroads went to sleep, doing their standardized business in a routine way until the juggernaut of human progress caught up with them and is now in process of showing old managements what happens to those who lag behind. For, in this period of inactivity of the railroads, the automobile engineer came to the front. He built mobile road units in the form of trucks, motorcoaches, passenger cars and delivery vehicles, and designed as well the business systems and the road arteries that were necessary for the new industry.

The motor-car of today does its particular work in extended fashion, and, because the automobile engineer has developed to more refined thinking on the old problem of transportation and its vehicles, he can see the mess into which the railroads have got themselves and the cures for those ills to which they have fallen heir. The keynote of all progress today is research, so the automobile engineers are today getting a great laugh out of the railroads.

Meanwhile, however, some other things have been happening to which the automobile engineers have perhaps been as blind as the railroad men have been to automobile development. The motor-car company that is not connected with an aeronautic development today is, of necessity, sadly behind on what aviation can give to the motor-car business.

Aviation designers think in terms of structure first. This word structure has an entirely different meaning to an aeronautic man than to a motor-car man. To the latter, structure is perhaps what makes the car hold together, which is all that it must do to perform its function. Aviation, however, is forced to look at structure from a much more careful standpoint. If a motor-car engineer adds 100 lb. to his car, it means little to him other than thickness of castings and a few cents more of material expense, and the purchaser of the car pays the bill for hauling this 100 lb. around during the entire life of the car. Even so, the 100 lb. makes little difference in the expense.

In an airplane, 100 lb. of extra weight figures out about 5 cents per lb. per hr. in the air, or $5 per hr. or $40 per 8-hr. day expense for the operator to carry this around. Theoretically, for the air-transport designer to save 1 lb. in the structure of his airplane is worth $30, for which reason the airplane engineer has become the most refined structural analyzer in existence. The public is accustomed to thinking of airplanes as flimsy because they are light, but airplane structures are by far the strongest that have been built for transportation of any kind.

The aeronautic industry has laid at the door of the automobile industry 20 times more possibility of profit than its group of executives have had the vision to absorb. Had they put a stress-analysis man to work to study the car as a structure, they could have taken half of the weight out of it at any time for no cost.—From a Summer Meeting paper by William B. Stout, Stout Engineering Laboratories, Detroit.

MASTERY OF DETAILS BRINGS PROGRESS

I FEEL that the great advances in the performance of engines have come from engineers who have kept the fundamentals constantly before them and tried to meet these fundamentals by a steady progress in details of design and materials. I find that the great progress in manufacture and sales have come from those who can master details.

Success depends upon the ability to see that an infinite number of things are done just right and that almost 100 per cent of the product approximates uniformity.

In the development of our engines we have a book listing the important items for the checkers of the drafting room to look for in a new design. This book represents the accumulated experience of service, manufacturing and design difficulties. On the list of important parts of an engine are more than 400 points on which the checkers check a new design, and these do not include a large part of the dimensions.

After an engine has got to the research laboratory, it may be on the block and on the road for five months, and what happens there is a headache.

The engine does not look the same to different departments. The inspection department has a viewpoint all its own, consisting of a very critical consideration of everything that has been done. When it comes to bat, it has 353 formal matters that it examines carefully on the important parts.

When the engine is ready for manufacture, the shop has to consider and reckon with the decisions everyone has made while the engine was being designed. Here the battle of details is staged, for the efforts in design, checking, research and inspection all come to their day of reckoning.

The final test before shipping has a list of points as long as your arm; and then comes the test in real service.

After all this, the service department has very profane ideas about the product.

So far as designing and manufacturing engines is concerned, success is nothing short of taking infinite pains.

The reason why men succeed who pay little attention to theory is that they have mastered the many necessary details that are essential to success.—From an Annual Meeting paper by H. L. Horning, S.A.E. Past-President, president, Waukesha Motor Co., Waukesha, Wis.

SOME COST-SAVING METHODS IN MOTORCOACH UPKEEP

By R. M. AHRENS

A brief description of the work required of the motorcoaches maintained by his company is given by the author, who states that the constant and ultimate aim of the department head who handles repairs and replacements is to keep down the cost per mile of operation. In compiling statistics of this cost, all charges against maintenance are divided into 30 distinct classes. As statements are made up, each item of the 30 classes can be compared directly with previous statements and a finger put directly on those items showing undue rise and serving to keep the total-cost-per-mile figure high.

The author then describes certain special maintenance shortcuts and methods peculiar to the company's system which are followed in the three main service shops and greatly aid in retarding any advance in costs. Some of the subjects treated are: rebuilding of cylinder heads on engine blocks, the maintenance and reclaiming of clutch plates and differential gear-carriers, and the relining of shock-absorber barrels.

AT PRESENT, the Pacific Greyhound Lines operates 380 motorcoaches over 8325 miles of highway. The territory served by the main lines is bounded by Portland on the north, Salt Lake City on the east and El Paso on the south. The elevations attained on the four main routes are 4522 ft. on the Pacific Highway, 4223 ft. on the "valley" route to Los Angeles, 7135 ft. on the Salt Lake operation, and 5294 ft. on the southern route to El Paso, which route also runs below sea level for some distance. Our operation averages 1,548,431 miles per month, or 53,483 miles per day. As the equipment is widely diversified regarding makes of vehicle and engine power, making standard practices rather hard to use, certain special shortcuts and methods peculiar to the system are followed in our three main service shops, at Portland, Oakland and Los Angeles.

In handling repairs and replacements on motorcoaches of any of the larger systems of the Country, the constant and ultimate aim of the department head is to keep down the cost per mile of the operation. In compiling statistics of our company to determine this cost, all charges against maintenance are divided into 30 distinct classes. Therefore, as statements are made up, each item of these classes can be compared directly with previous statements and we can put a finger directly on those items showing undue rise and serving to keep the total cost per mile high.

Experience has shown that certain of the classifications maintain almost a constant figure, are necessary to continued operation and obviously cannot be reduced below a certain point. These items are watched closely, but we realize that they can be reduced very little no matter how much effort is expended. On the contrary, certain types of cost figures have a tendency to mount alarmingly if not watched closely. A few methods developed and used in our three main shops, which greatly aid in retarding the advance in costs, will be discussed.

Factors Tending to Increase Costs

The highest single item on the long list tending to shove these variable classifications skyward is the cost of new replacement parts for engines, bodies, chassis and running gear. Obviously, the best method of keeping this item as low as possible is the reconditioning of worn or used materials. This comes in the natural course of maintenance procedure when dealing with such operations as grinding valves and reboring blocks; but, when dealing with certain smaller items, it is not even considered by the smaller bus operator. Certain special procedures in maintaining a large fleet, such as is operated by our company, are worthy of note.

The engine part most often requiring attention and changing is the cylinder head. If we think that the purchase of a new cylinder-head casting is necessary after grinding valves four or five times until the seats are worn down too far to be usable, which is a common procedure when no attempt is made to reclaim the head, the cost of valve-seat wear will be very high. By welding new metal to worn valve seats and then refinishing them to original standards, the normal life of cylinder heads in many instances can be tripled. The welding is done with an oxyacetylene torch, using cast-iron metal-weld rods; if necessary, worn valve seats can be built up as much as 1/4 in.

Since the exhaust-valve seats usually are the only ones needing repair, the intake seats are protected during the welding process by a round carbon plug of the correct size to fit in the intake-valve opening, thus preventing welding metal from building up on the intake-valve seat. In the welding procedure, one end of the cylinder head is preheated at a time, using two torches fed by city gas. Experience has shown that heating one end individually assists greatly in avoiding warping. While one end is being preheated, it is protected by insulation, the other end being entirely open to atmospheric temperatures. After worn exhaust-valve seats are built up, the carbon plugs are removed from the intake seats and the unit is ready for machining.

Machining Heads After Valve-Seat Welding

In machining, the head is first placed on a milling machine and faced off across its entire length to remove any warping that might have occurred and to true the whole assembly. Then, by using a special cutting-head for each model, the combustion chamber is cut to the exact dimensions of the original specifications. Thus all surplus metal deposited when the welding is done is cleaned out and the

[This paper was presented at a meeting of the Northern California Section. The author is general superintendent of maintenance and equipment for the Pacific Greyhound Lines, Oakland, Calif.]

head has the same combustion space as was provided in the casting when new. The casting is next placed on a jig that aligns the exhaust-valve seats in a plane perpendicular to a drill reamer, which cuts the valve ports to the original diameter. The drill reamer is set and then centered by using a plug guide which fits in the valve-stem guide of each port. After this step is completed, the valve seats are reamed and ground by hand.

Various makes and types of insert seats have been tried during the last four years, including screw and press-type seats of materials that are harder than cast iron. None of these patent seats has as yet proved successful in our experience because of the difficulties of keeping them in place. Loosening and cracking have been the cause of more trouble than the results obtained were worth; however, when properly developed, this type of seat may have great possibilities.

Compared with the usual procedure of some of the smaller bus-operating companies, the saving by following the method just outlined amounts in most cases to almost $100 per head handled, as the average new head casting costs about $140. When completed, the job is as serviceable and will give the same mileage as a new casting. Thus a unit which would normally average 66,000 miles before renewal is made to run 175,000 to 200,000 miles before scrapping.

At the same time as the valve seats are welded, a search is made for cracks in the casting, and if any are found they are welded. In most cases, the cracks are of such order that welding is simple and requires very little time. Larger cracks are sometimes encountered that make it uneconomical to try to reclaim the unit. About 60 per cent of the heads will show from one to four small cracks every time they are sent in for overhaul.

How Clutches and Differentials Are Reconditioned

The average transmission and clutch assembly will run about 60,000 miles between periods of necessary repair work. At every other period of taking the unit out of service for repair, the flywheel pins and pinholes in the center clutch-plate are found to be worn out of round, the amount of wear sometimes being as much as 1/16 in., which makes the unit unfit for service. Replacing of the pins is therefore necessary, but it has been found to be feasible to recondition the plate by filling the holes by welding, machining the face of the plate and boring out the holes to standard size. The cost of the operation on the plate is about $2.50, whereas a new plate costs $22.50 or more.

Overhauling of differentials has been found necessary on an average of 68,000 miles, and many cases of worn compensating-gear carriers have been found. The small gears on the compensating spider gradually wear out a race in the housing which carries them, the depth of the cut often amounting to 1/16 in. Our practice in the past and also that of the smaller operator, has been to junk the carrier in this condition. Now we build up these carriers by electric welding and then machine them to original dimensions. The welding operation requires about 2 hr. for the eight separate welds on the assembly. Machining requires about 1½ hr. Since an average price of the new unit is $30, the saving is appreciable. When reconditioned, the service realized is practically the same as that of a new assembly.

On the front casting of the differential, the pilot-bearing seat, which is cast integrally with the steel housing, becomes out of round and unusable after a period of service. This seat also is built up by welding. The process is exacting as to both welding and machining, because the material of the casting is exceedingly tough. After the machining, the cut on the lathe is undersize, and the finished surface is ground to be 0.001 in. undersize to afford a good press fit.

Substantial savings effected by the two operations on differentials have kept down an otherwise high cost of differential maintenance.

Shock-Absorber Barrels Relined

The average air-type shock-absorber will run 150,000 or more miles before requiring overhaul. When overhauling it, the necessary work includes refinishing the barrel. To get the required finish, we have found it necessary to take out 0.020 in. each time. A shell could be reconditioned three times, after which a new shell would be necessary because the wall thickness would be too thin. But our company has found it decidedly economical and satisfactory to press into this shell, at the end of its third period of wear, a brass liner or sleeve. This sleeve, when first placed, is 0.020 in. under size. It, in turn, is rebored 0.020 in. after each interval, until it is down to 0.040 in. oversize. By this time it usually has been damaged by some accident, after having given more than 1,000,000 miles of service. The sleeve itself is about ⅛ in. thick.

Another advantage of the brass sleeve is that, whereas the wall in the standard cast-iron sleeve is always found to be scored after a period of wear, the combination of iron piston and brass sleeve eliminates all scoring by wearing to a very smooth working surface; hence the life of the unit between overhauls when using the brass sleeve is longer than when using the cast-iron barrel.

Large Operators Maintain Unit-Repair System

Numerous other special repair procedures of the foregoing nature are daily followed in the shops of the various large fleet operators. Motorcoach maintenance is essentially a problem of keeping all equipment in good operating condition at the lowest cost possible. The condition of any bus-maintenance system is always reflected in the cost-per-mile figure from month to month and in the number of failures of coaches on the road. Definite mileage schedules for inspection, greasing and changes of the various units of the coach are necessary, supplemented by closely kept records of the dates of the different service operations.

Virtually all of the larger systems maintain their equipment on the so-called "unit system." Spare units of all parts of the coach are carried in the various shops, thus reducing delays to schedules and the holding of inoperative equipment to the minimum. This unit system means that a bus will lose all identity after less than two years, the only thing actually remaining with the vehicle being its number, because units are replaced at set intervals.

The expenditure of dollars and cents in small amounts here and there has been found to be the largest factor in determining whether that oft-repeated term, "cost per mile", will remain at a satisfactory low point during the life of the bus or will mount to more and more as the vehicle grows older.

Pertinent Pokes for Satisfied Engineers

By Herbert Chase

"IN making these comments," Mr. Chase says, "I am well aware that engineers are rarely given an opportunity to design a car incorporating even a large proportion of the improvements they would like to see included.

"Unless some more or less 'ideal' types of construction are visualized, however, there may be no well-considered objective."

Visualizing these "more or less ideal types of construction," Mr. Chase, in the following paper, throws a blanket indictment at the car designers, says what he thinks about current automobiles in no uncertain terms, and states specifically what he thinks ought to be done about it.

Bodies, frames, springs, headlights, seats, engines—no unit of the modern car escapes Mr. Chase's stimulating criticism.

PRESENT cars are much too uncomfortable. They are unwieldy. Even for their size they are too heavy. In consequence they cost too much to build and to operate. They are not sufficiently safe. They are too complex in construction and operation. They involve many petty annoyances. They lack many desirable refinements. They are too hard to service.

Aside from these and a few other shortcomings, they are pretty good cars!

Discomfort No Delusion

Present cars are uncomfortable partly because discomfort starts even before one gets into them—on the way in, in fact. So far as the driver is concerned at least, the discomfort often lasts for some time after he gets out! In the interim, it persists in varying degrees. One wit has said you can't even spit out of the present car without discomfort. He's right.

Mr. Chase, a consulting engineer of New York, read this paper at the 1933 annual meeting of the Society.

Before I run out of adjectives, perhaps I should say that the present-day car is needlessly, even absurdly low. This phase of construction might be called "low-down" engineering, one of the lowest forms. In reference to the seats, however, the cowl bar is cruelly high. It is not a mere question of the driver seeing the front fenders—if he has any left. I have ridden in cars in which, when seated, I could barely see the radiator cap. By craning my neck I could see a little road far ahead of the car.

Low-Down Engineering

Call this exaggerated if you like. It applies to many cars, however, as well as to a large proportion of drivers, both male and female, and it's serious. It is one factor in making cars uncomfortable and unsafe. It is extremely tiring and for that and other reasons it is dangerous.

What's the excuse for this type of construction? There are two:

(1) it looks better and (2) a low center of gravity makes for safety.

Let's analyze these "reasons." I readily concede that modern cars, in general, have achieved fine appearance and I am mindful that "looks" are a great sales asset. I concede also that present cars look better than some which were much more comfortable, so far as vision and certain other features are concerned, a few years back.

What I strenuously deny is that good looks cannot be secured without absurdly low bodies, which are hard to enter and to leave. I also deny that a combination of high cowl and low seats is either essential or desirable. Body designers created this style. It's up to them, I think, to get us out of this ill conceived phase of low down engineering and to show us something rightly proportioned and even better looking! I am satisfied not only that this can be but that it must be done.

As to that low center of gravity, let's remember that a moderately low center of gravity has an advantage chiefly in helping to prevent the overturn of a car. But overturning rarely occurs even with high centers. Too low a center, on the other hand, tends to increase skidding tendencies and to reduce the pressure of outer tires against the road (as compared to a higher center) when rounding a curve. This results in instability and creates, I believe, a far worse hazard then the high center of gravity.